# Edinburgh Tram Network

## *Report on Phase 1a / 1b Separation*

Doc. Ref: ULE90130-SW-REP-00529 V1

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7 December 2007

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**Revision History**

| Ver. No. | Date | Description | Prepared By |
|---|---|---|---|
| 1 | 7 Dec 07 | First Issue | J Brown |
| | | | |
| | | | |
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**Distribution**

| Ver. No. | Date | Name | Role | Company |
|---|---|---|---|---|
| 1 | 7 Dec 07 | Damian Sharp | Contract Representative | tie |
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## 1. INTRODUCTION

Due to potential funding issues, **tie** is considering whether the Edinburgh Tram Network (ETN) might be carried out in two Phases, 1a and 1b. However, **tie** wishes to understand the implications of proceeding with the construction of the section between the Edinburgh Airport and Newhaven, known as Phase 1a, with the section from the proposed Roseburn Junctions to Granton Square, known as Phase 1b, being built at a later date.

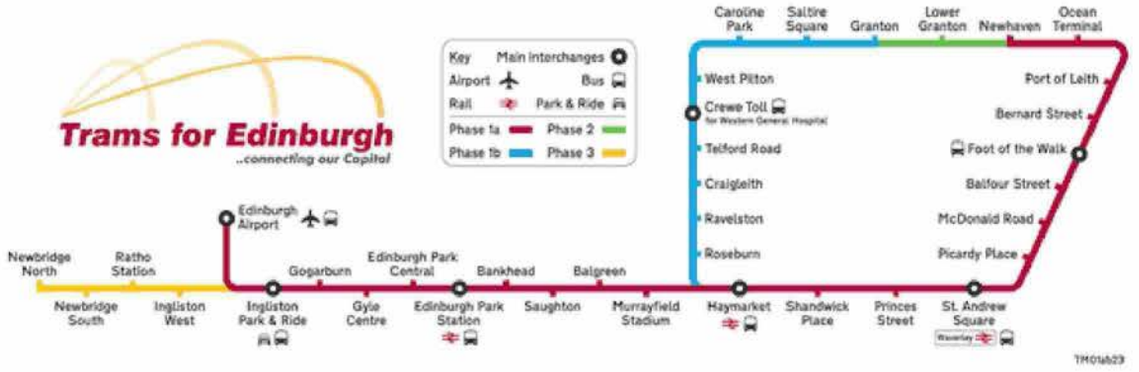



Figure 1 - The construction phases of the Edinburgh Tram Network

### 1.1 Change Order Description

The preparation of a report and advice to **tie** of all the implications to the design process and anticipated implications to the construction, commissioning and planning processes necessary to accommodate this requirement to ensure that Phase 1a is designed and constructed so that it is able to operate independently of Phase 1b. In addition, **tie**'s objective is that in the event that Phase 1b is to be constructed at a later date than Phase 1a, it should be done with the minimum disruption to the Phase 1a full operational service.

The review report will include but not be limited to such aspects as the infrastructure and anticipated system design, the construction of the infrastructure necessary for Phase 1b at its interface with Phase 1a, the implications on the Traction Power (Substations and Overhead Line Equipment), Supervisory Control and Communications, the Gogar Depot, the Operations Control Room and associated Equipment Room etc. This will include assistance with the identification of any possible implications, limitations and restrictions regarding construction access to the Phase 1b site.

## 2. EXECUTIVE SUMMARY

This report describes the design and infrastructure issues arising from the potential separation of the construction of Phases 1a and 1b. It considers optimistic and pessimistic scenarios where these differ significantly.

It states that, depending on **tie**'s reaction to the implications of the report, further investigation, design and consultation actions might be necessary.

In addressing the issue of Trams, it concludes that tram considerations are not pivotal to infrastructure considerations but that stabling and commissioning will need to be considered.

It concludes that the track should be laid as plain line at the Roseburn Junction and in the Depot sidings. At the Roseburn Junction, sufficient track slab should be installed at Phase 1a to enable the continuity of operation of Phase 1a during the construction of Phase 1b. The installation of plain line is recommended for both safety and longevity.

It recommends that little special provision need be made for Track Auxiliaries except that equipment should be bought in advance for Phase 1b if it is likely to be built shortly after Phase 1a to avoid obsolescence issues.

The report addresses the need to divert the existing walkway / cycleway at the Roseburn Junction arising from the Phase 1a works burying the existing route. It sets out the optimistic and pessimistic options for doing so.

There are no issues for structures as the only structure affected is designed to carry the West Roseburn Junction and it would not be economic to provide this in stages.

The Traction Power Supply issue is addressed at length. Much of the critical decisions revolve round its strategic specification and design. This section describes simulation studies and discusses in some detail the implications for each option.

In contrast, the issues applying to the Depot are not critical, limited to stabling and consideration of the provision of minor items.

The indicative design of the Overhead Line Equipment would only minor changes to accommodate the separation of the two phases.

The report recommends that the Operational Data Network is provided as planned but that a termination frame for the optical fibres at the Roseburn Junction to facilitate a later extension be provided. For the telephone system and the Operational Radio Network, it is recommended that the full facility is provided, only omitting the equipment on Phase 1b route.

The report concludes that, other than its interface with the Supervisory Control and Communications there are no pivotal issues for the Integrated Fare Collection system.

The Low Voltage Supply system is to be provided by the Distribution Network Operator to each facility and therefore there are no issues arising from it.

Street Lighting needs to be provided where the Roads are altered.

The report proposes no difference to the Drainage system between the optimistic and pessimistic scenarios. Phase 1b works in the vicinity of the junction drain into the Phase 1a drainage system and these first works can simply be truncated at the planned access chambers.

The main issue for Cable Ducting is the architecture of the Traction Power Supply system otherwise sufficient ducts for the whole system in the area of Phase 1a should be provided as part of the original works.

The necessary Utility Diversions should be redesigned to achieve an economical but practical diversion as part of the Phase 1a works.

Geotechnical works will be required to the extent necessary to support Phase 1a but also facilitate the chosen option for the Road diversions.

The landscaping requirements will follow decisions on the Road options and the resulting earthworks.

The report also addresses the implications and restrictions to construction access to the Phase 1b site. It points out that if works are carried out in the Roseburn Junction area to avoid abortive works for Phase 1b, then the construction access from Russell Road will not be available for the substantial works for Phase 1b.

The report concludes that Operational and Maintenance issues make no material difference to the design and construction of Phase 1a.

## 3. DESIGN PROCESS

In accordance with the requirements of their Agreement with **tie**, SDS is in the process of finalising a detailed, approved and approved Infrastructure design for Phase 1a and Phase 1b in combination.

It should be noted when **tie** has considered the implications of the various sections of this report and decided on a detailed specification for the options, it will be necessary for SDS or its preferred InfraCo Bidder, to undertake the consequent investigation, design and consultation actions needed to implement **tie**'s strategy.

### 3.1 Optimistic

Design changes will be necessary to determine appropriate temporary cut-off of the Phase 1a works and the consequent connection design for the 1b contract.

### 3.2 Pessimistic

Design changes will be more extensive because they will need to embrace abortive works and arrangements in addition to those described in the Optimistic Scenario above.

## 4. CHOICES

It is considered that there are two essential choices available to **tie** on the approach to the separation of Phases 1a and 1b.

### 4.1 Optimistic

One scenario is that **tie** believes that the construction of Phase 1b, although not to be constructed at the same time as Phase 1a is, nevertheless, likely to happen in the short to mid-term, say, within five years.

The approach to decision-making would therefore be on the basis that abortive work is to be avoided in favour of doing sufficient of the necessary Phase 1b permanent works to enable Phase 1a to be constructed without abortive works. This would tend to mean that Phase 1a would cost more from the outset but overall, public money would not be wasted on temporary works and the future provision of Phase 1b would be at the least possible cost giving it the best chance of early implementation.

### 4.2 Pessimistic

In this scenario, **tie** believes that the construction of Phase 1b is unlikely in the medium term and its protection is its only need at the stage of constructing Phase 1a.

The approach to decision-making would therefore be to minimise the cost of Phase 1a commensurate with protecting but not otherwise providing for Phase 1b. This would mean that the cost of Phase 1a would be the least possible but Phase 1b would be more expensive.

### 4.3 Application of Scenarios

Each technical issue includes a review of the differences between the two scenarios. This will inform **tie** of the consequences of each approach.

In some cases, there is no difference between the two approaches.

## 5. TRAMS

It is understood that the TramCo tender provides two options over and above the basic quantity of 27 trams required to run the full service on Phase 1a. Option 1 provides for a further four trams to run the services on Phase 1b and Option 2 provides for a further four trams to cater for increased demand on the system generally.

The Optimistic and Pessimistic scenarios do not present any particular issues for the trams and are not pivotal to the considerations. They present the following considerations:

### 5.1 Optimistic

The Optimistic scenario is that the basic tram quantity plus Option 1 will be ordered and delivered as part of Phase 1a.

This option would include the construction of sufficient sidings at the Depot to accommodate the basic quantity of trams plus Option 1 (31 in total).

The consumable spares holding would be sufficient for this fleet although 'change-out' and capital spares are not sensitive to the optimistic and pessimistic scenarios and would probably be unaffected.

### 5.2 Pessimistic

The pessimistic scenario is that the go-ahead for Phase 1b will be given after the validity of Option 1 expires. This means that 27 trams will be provided and catered for without additional sidings or spares.

The extra trams would have to be commissioned and test run out of service hours to avoid service disruption on Phase 1a.

The supply, installation and electrification of the additional stabling sidings needed, would be added to the Phase1b programme and costs, as would the resulting modifications to the power supply and Control Room equipment.

The extra unit cost of consumable spares should be negligible.

## 6. TRACK ALIGNMENT

There is only one option recommended for the track construction whether **tie** adopts an optimistic or pessimistic approach on other technical issues. The omission of the switches and crossings forming both the eastern part of the Roseburn Junction from the Phase 1a works and the additional Depot sidings is recommended for all but the shortest delay between the construction of the two phases.

It is recommended that, to avoid excessive uneven wear, avoiding maintenance liability and eliminating the hazard of tram derailment, the switches and crossings forming Roseburn Junction East would not be installed during Phase 1a. It is recommended that, subject to the InfraCo's method of working and programme, removal of plain line rails, installation of all switches and crossings and associated testing and commissioning of the track could be undertaken in a long (typically 52 hours) weekend type possession of the Phase 1a tracks.

### 6.1 Roseburn Junction

To facilitate the installation of all switches and crossings at the Roseburn Junction, the design of the track structure to be constructed in Phase 1a would incorporate a stub-end section of track slab at Roseburn Junction East. The length would need to be determined but is not critical. This stub-end would be along the line of the Roseburn Junction eastern spur tracks as they turn out from the double junction, to a point where construction of the remainder of the eastern spur track slabs, to the north, and their connections with the Phase 1a stub-end section, could be undertaken during works for Phase 1b without adversely affecting the normal service conditions of Phase 1a.

During the construction of Phase 1b, it is anticipated that removal of the plain line rails, the installation of all switches and crossings and associated testing and commissioning of the track and auxiliaries, could be undertaken in a long (typically 52 hours), weekend type possession of the relevant Phase 1a tracks.

Dwg. No. ULE90130-02-DRG-00007 of the proposed arrangement at Roseburn Junction East and its approaches either side in the alignment of the Edinburgh Airport – Haymarket tracks that would not require modification during Phase 1b works is attached.

This, in effect, would constitute passive provision for Phase 1b.

### 6.2 The Depot Sidings

The Depot has been planned and sized for the servicing and accommodation of the full complement of trams (27+4+4) which may be ordered by **tie** for the full operation of Phases 1a and 1b. However, if only Phase 1a is to be constructed in the short term, the two most northerly storage sidings can be omitted.

These two sidings need only be installed to accommodate additional trams which will be required for the subsequent operation of Phase 1b and any increase in service frequency.

Dwg No. ULE90130-06-DEP-00001 attached, shows the proposed arrangements.

# 7. TRACK AUXILIARIES

## 7.1 Introduction

All of the current Track Auxiliaries documentation for points, point indicators, heaters and signals etc., was written as 'generic documentation' regardless of their position or function.

Details of the position of switches and crossings are contained within the Track Alignment designs and the function of each switch and crossing is contained in the Network Diagrams.

Any change in position, function or deletion/addition of switches or crossings would have no impact upon the documentation listed above or in any of the Safety, Reliability, Maintainability documentation.

However, there are a number of interfaces which could be affected by the separation of Phase 1a and Phase 1b construction and these include, but may not be limited to:

- Cable route provision – this is dealt with elsewhere, but the later provision of track auxiliaries would need to be taken into account in the initial provision and design.
- Auxiliary power provision – this is dealt with elsewhere but the later provision of track auxiliaries would need to be taken into account in the initial provision and design.
- Communications with the TPDS and allied systems: - see under System Control and Communications.
- System Overview Displays – a decision will need to be made on what the initial provision should be, taking into account obsolescence and other considerations.

Thus separating Phases 1a and 1b would not have any significant impact upon the Track Auxiliaries documentation.

## 7.2 Staging of the Works

Regardless of whether the Roseburn East and West Junctions pointwork is installed and 'clipped and scotched' or plain-lined, the track auxiliaries should not be installed as the communications network for Phase 1b will not be in place and therefore the communications architecture will be incomplete.

It is also suggested that where the content of trackside cubicles, ducting etc., is only partially utilised for Phase 1a, that passive provision for the accommodation for Phase 1b, equipment be included.

## 7.3 Optimistic / Pessimistic

In both scenarios, only the equipment needed would be bought for each phase. There might be a need to buy interface hardware for the Supervisory Control and Communications and this is dealt with in that section.

# 8. ROADS

## 8.1 Roseburn East and West Junctions

The footway / cycleway linking Russell Road to Balbirnie Place and the Roseburn footway / cycleway will be severed by the construction works of Phase 1b. The footway / cycleways are part of the Caledonian Cycle Track which is an Adopted Road maintained at public expense.

At this point where the existing footway / cycleway 'doglegs' to gain height, Russell Road goes under the main Edinburgh to Glasgow Railway Line which formed part of the former North British Railway. The Caledonian Cycle Track is on the formation of the former Caledonian Railway which was grade-separated from the North British line and above it.

This results in a considerable level difference between Russell Road and the general level of the Caledonian Cycle Track which the Phase 1b route has gained when it reaches Roseburn Terrace Bridge.

The route of the existing footway / walkway is close to the alignment of Phase 1a and the earthworks required for Phase 1a will bury part of the footway / walkway. It is also affected by the underline bridge to be constructed over Russell Road which will support Roseburn West Junction.

The planned replacement footway / cycle route on the west side of the alignment rises from Russell Road and needs most of the distance between Russell Road and Roseburn Terrace to gain the necessary height at a gradient of 5.86% . Each ramp section is 10m long with landings of 1.8m length between.

The existing footway / cycleway is lit and so either temporary or permanent replacements would also need to be lit to a similar standard.

## 8.2 Optimistic

The optimistic option is to undertake the earthworks and construction required for the permanent works for Phase 1b. This comprises an inclined footway / cycleway ascending to track level from Russell Road going north, a track crossing and a descending footpath / cycleway that joins Balbirnie Place. To facilitate this approach, the Phase 1b earthworks would be required between the Roseburn Junction and Roseburn Terrace underline bridge. This would avoid abortive works but would cost more in the first instance.

## 8.3 Pessimistic

With the pessimistic scenario, a temporary arrangement would be constructed to maintain this essential link. This would minimise the initial cost, including earthworks which are dealt with elsewhere but would result in abortive costs when further changes would be necessary for the construction of Phase 1b. The existing link is not compliant with the guidance associated with the Disability Discrimination Act and a temporary link would not need to be either.

The temporary route would need to be lit and this is dealt with elsewhere.

## 9. STRUCTURES

The only structure affected by the construction of Phase 1b is the Russell Road Underline Bridge. This will carry the Newhaven to Airport route but SDS has designed it to also support the possible additional future west to north chord that would enable a direct route from Granton to the Airport.

The design is for a single efficient structure. This will be constructed as part of Phase 1a.

There are therefore no structural issues arising from the separation of Phases 1a and 1b, save that the west to north route will be unused until the construction of Phase 1b is completed.

There is an impact on the Roads, earthworks and landscaping provisions because the structure will be built over the existing Caledonian Cycle Way, an adopted Road. These are dealt with in the respective sections of this report.

The General arrangement of this bridge is shown in Dwg. No. ULE90130-05-BRG-00004 attached.

# 10. TRACTION POWER SUPPLIES

## 10.1 Introduction

### 10.1.1 Design Considerations

For Light Rail and Tramway systems, the needs of traction power supply are driven by simplicity and lightness of vehicle equipment, and electrical safety and clearance considerations. Therefore, contrary to main line practice, transmission of energy over long distances is not a consideration, frequently-spaced substations in fact bringing advantages in diversity and supply reliability. Overhead current collection is therefore standard for new systems at relatively low dc voltages of 750V or 1500V. For street-running tramway systems in the UK, a nominal voltage of a maximum of 750V is the established norm. All these types of system use the running rails as the traction return circuit.

The design of the traction power system for Edinburgh Tram Network follows these general principles. The design is system-specific and is tailored to a number of factors and requirements:

- The LRT network envisaged;
- The type of vehicle to be used;
- The gradient profile;
- Distances between stops;
- The service pattern to be operated;
- Availability of power supplies; etc.

This study reviews the system's capabilities in terms of all four of the original electrical design criteria:

- Current-delivery capability;
- Acceptable pantograph voltage;
- Protection discrimination (fault/load margins); and
- Acceptable track voltage (accessible and touch voltage).

### 10.1.2 Design Principles

In common with modern tramway practice, the 'in' and 'out' lines are cross-connected with each other and to parallel reinforcing dc cables at frequent intervals, each section between substations being operated as a double track single circuit. Main line sections are wherever possible fed from both ends, the exceptions being at terminal sections which are single end fed. Each electrical section is normally linked through to the next

via the substation switchgear, so effectively all trams on the system are fed from all substations, the relative contributions of course depending on the relative distances between the substations and the trams.

The design takes account of the requirement that the system is to be able to support the full specified tram service with any one substation out of service, noting that there are two types of substation outage to consider:

Acting in 'Track Paralleling' mode (not feeding, but dc switchgear connected to the OLE); and

Substation 'Disconnected and Bypassed' (disconnected by means of feeder isolators and bypassed through substation bypass isolator).

For a cross-connected system such as Edinburgh, these two outage modes yield almost the same electrical results, but the protection applied to each is different and requires separate analysis.

10.1.3 Service Pattern

Our understanding from the Operator of the levels of tram service to be operated under the two phasing construction scenarios is as follows:

| **Phase options** | **Service 1: Ocean Terminal-Airport** | **Service 2: Newhaven-Haymarket** | **Service 2 ext: Newhaven-Haymarket-Granton** | **Combined services (core section)** |
|---|---|---|---|---|
| Phase 1a only-Initial service | 6 trams/h 10 min headway | 6 trams/h 10 min headway | - | 12 trams/h 5 min headway |
| Phase 1a only-Enhanced service | 8 trams/h 7½ min headway | 8 trams/h 7½ min headway | - | 16 trams/h 3-4 min headway |
| Phase 1a only-Ultimate design | 12 trams/h 5 min headway | 12 trams/h 5 min headway | - | 24 trams/h 2½ min headway |
| *Phase 1a + 1b-Initial service | 6 trams/h 10 min headway | - | 6 trams/h 10 min headway | 12 trams/h 5 min headway |
| *Phase 1a + 1b-Enhanced service | 8 trams/h 7½ min headway | - | 8 trams/h 7½ min headway | 16 trams/h 3-4 min headway |
| **Phase 1a + 1b-Initial service | 8 trams/h 7½ min headway | - | 8 trams/h 7½ min headway | 16 trams/h 3-4 min headway |
| Phase 1a + 1b-Ultimate design | 12 trams/h 5 min headway | - | 12 trams/h 5 min headway | 12 trams/h 5 min headway |

Notes: * For Phase 1b opening and operating with Phase 1a.

** For Phase 1b opening and operating after Phase 1a.

1.1.1 Effects of separating Phases 1a and 1b

The traction power system for the Edinburgh Tram Network was designed on the assumption that Phases 1a and 1b would both be constructed, and indeed would be available at the same time, so as to support each other electrically. Delaying or abandoning Phase 1b would result in Phase 1a having to be designed to support the full

specified tram service from Newhaven to Edinburgh Airport without the power feeding contribution from the Roseburn corridor traction substations, under the specified substation outage conditions.

Owing to the interconnected configuration of the dc traction system, it is not just at the interfaces between Phases 1a and 1b that the effects of separation will be felt. If fewer substations are built (at least initially) the resulting reduced power contribution will impact on every tram in service. However, the proportion of current fed past substations from more remote substations is relatively low, and of course decreases as the distances between individual trams and substations increase. We have therefore restricted this separation exercise to the substations and electrical sections adjacent to the Phase 1a/1b interfaces, extending the study where necessary to include the 'substation Out of Service' (OOS) conditions defined above. There are therefore two interface areas to study:

**Newhaven / Leith**: Boundary with Phase 1b substation 'Tram Granton View' (GVE) across the future Phase 2 'gap'), requiring study of normal feeding conditions, plus outage conditions at Phase 1a substations 'Tram North Leith Sands' (NLE) and (or) 'Tram Leith Walk 163'.

**Roseburn Junction**: Boundary with Phase 1b substation 'Tram South Groathill Avenue' (SGE), requiring consideration of the need for Tram Russell Road track paralleling hut (RRE), study of normal feeding conditions, plus outage conditions at Phase 1a substations 'Tram Haymarket Terrace 1' (HTE) and (or) 'Tram Jenner's Depository' (JDE).

These studies are described in detail in Sections 10.2 and 10.3 respectively.

10.1.4 Study software and methodology – general

Previous decisions to remove Section 4 from the initial build phase of the ETN impacted the Traction Power Supplies by potentially removing the opportunity to double end feed the section between LWE (Tram Leith Walk TSS) and NER (Newhaven Road) under out of service conditions.

Under Vossloh PowerPlan simulation, it was demonstrated that this created difficulties with Pan Voltages at NER and generally with Rail Potentials in the LWE (Tram Leith Walk 163 TSS) to NER area.

To remedy this problem in a cost effective manner SDS proposed to create double end feeding by bridging the Section 4 gap with DC link cables (Positive and Negative).

In removing Phase 1b without remedial action we potentially re-instate the difficulties we have overcome. This is also compounded by selection of a tram having a slightly more onerous electrical duty cycle than the generic tram utilised in previous studies.

Knowing that the principal difficulties rest with pan voltages and rail voltages at NER, the principal focus of this modelling exercise was to assess the full impact of Phase 1b delay on voltage levels at the extremes of Section 1.

To assess the options for the traction power supply with regards to separating Phases 1a and 1b, SDS have utilised a nodal analysis tool called **B2SPICE (V5)** to develop electrical models of the infrastructure as follows:

Newhaven Study:

Model 1 – (Existing Condition) – Newhaven Road (NER) – Tram Cathedral Lane TSS (CAE) with Tram Granton View TSS (GVE) feeding towards NER via DC Link cables.

Model 2 - Newhaven Road (NER) – Tram Cathedral Lane TSS (CAE). No Link with GVE. (This simulates total separation of Phases 1a and 1b).

Model 3 - Newhaven Road (NER) – Tram Cathedral Lane TSS (CAE). New Sub-Station included at LDE (Tram Leith Docks TSS).

Roseburn Junction Study:

Model 4 – (Existing Condition) – Tram Jenner's Depository TSS (JDE) – Tram Cathedral Lane TSS (CAE), South Groathill Avenue TSS (SGE) to Roseburn Delta.

Model 5 – Tram Jenner's Depository TSS (JDE) – Tram Cathedral Lane TSS (CAE). SGE to Roseburn Delta removed. (This simulates total separation of Phases 1a and 1b).

Model 6 - Tram Jenner's Depository TSS (JDE) – Tram Cathedral Lane TSS (CAE). SGE to Roseburn Delta removed. Tram Russell Road TPH removed.

Note: The purpose of creating Model 1 and Model 4 for the existing conditions was to validate the general models against previous numerical calculations and simulation output. (This has produced the desired output in both cases).

In both studies SDS have utilised source data in the form of existing DC Feeding and Sectioning diagrams, Traction Substation Equipment Specifications, OLE layouts and conductor data to build accurate models of the existing scheme and proposed schemes to enable thorough analysis of the options available.

Each model is a resistive model simulating the conductors in the configuration proposed for the ETN. OLE contact wire, parallel reinforcement and running rails and cross connections are built into the models. Traction Substations are treated as voltage sources with a no load to full load resistance.

Accelerating trams are treated as current sources.

It is important to note that the switching functionality of the feeding and sectioning scheme has been built into each model to allow assessment of Out Of Service (OOS) feeding conditions.

Note: .pdf versions of the circuit models have been lodged in Hummingbird and are available for inspection on an 'as required' basis. The HB references are #74329 - #74339 inclusive.

10.1.5 Tram loads and timetable

It is important to note that B2SPICE tool is an extremely competent circuit simulator and extremely suitable for analysis of this sort, however it is not a dynamic simulator of the scale of Vossloh PowerPlan and as such, it is necessary to manually position electrical loads within each model.

For this analysis it was necessary to conduct an analysis of ETN runtime data to assess worst case tram loads and positions for each study.

It should be noted that electrical worst case tram loads and positions for each study have been determined from analysis of Phase 1a runtime data. To facilitate analysis, data has been provided by the SDS Simulations team in the form of tram graphs and runtimes data sheets for:

Phase 1a timetable with two services, each with 8 trams per hour per direction. (TIE4D).

Phase 1a timetable with two services overlapping, each with 12 trams per hour per direction (TIE4D).

In each case the critical determination was to identify accelerating trams and their location within the system whilst drawing maximum load current.

10.1.6 Input data for studies

Substations (study areas only)

The following chainage data for each substation has been utilised in the models principally to determine voltage and power infeed points and also substation to sub-station conductor lengths.

Newhaven Study

| Traction Substation | Identifier | Chainage (km) | Notes |
|---|---|---|---|
| Tram Cathedral Lane | CAE | 4.559 | |
| Tram Leith Walk 163 | LWE | 3.034 | |
| Tram Leith Docks | LDE | 1.854 | Proposed Only |
| Tram North Leith Sands | NLE | 0.504 | |
| Tram Granton View | GVE | 13.594 | |

Roseburn Study

| Traction Substation | Identifier | Chainage (km) | Notes |
|---|---|---|---|
| Tram South Groathill Avenue | SGE | 9.784 | Section 3 – To GRS |
| Tram Jenners Depository | JDE | 9.533 | Section 5 – To AIR |
| Tram Russell Road 22 | RRE | 7.838 | |
| Tram Haymarket Terrace 1 | HTE | 7.219 | |

10.1.7 Input data for studies

The following electrical data has been utilised to determine the makeup of voltage sources (Traction Substations), Overall resistance of positive and negative conductors between substations and Tram loadings for the design models.

| Device / conductor | Rating / cross section | Electrical data |
|---|---|---|
| **Traction Sub-Stations** | | |
| Rectifier | Open Circuit Voltage | 780V |
| | No Load to Full Load Resistance | 0.0185 Ohms |
| | Power | 1200Kw |
| **Conductor Particulars** | | |
| Contact wire | 120 sq. mm Cu/Ag | 0.2217 ohm/km at $60^{0}$C and 20% wear |
| Running rail | Ri53 Steel | 0.0523 ohm/km/rail at $40^{0}$C and 20% wear |
| OLE Reinforcement Cable (Positive) | 1000 sq. mm Stranded Aluminium | 0.0302 ohm/km at $60^{00}$C |
| Rail Reinforcement Cable (Negative) | 1000 sq. mm Stranded Aluminium | 0.0302 ohm/km at $60^{0}$C |
| Earth Leakage Resistance | Virtual Item | 50 ohm per 400m |
| **Tram** | | |
| Tram | CAF Edinburgh Tram Series | 1,433A (Includes +5% Tolerance as stated by CAF). |
| Auxiliaries | dc/dc converter | 95A max |

The following notes are critical to the development of each model:

The overall resistance of Positive track feeder cables between the TSS and the OLE are ignored. Connections between the TSS and OLE are considered perfect conductors.

The overall resistance of Negative track feeder cables between the TSS and the OLE are ignored. Connections between the TSS and OLE are considered perfect conductors.

The OLE for each track is Cross connected with parallel reinforcing cables on a typical spacing of 400m.

OLE to parallel reinforcing cross connections are considered perfect conductors.

Intermediate OLE interconnections are ignored in the models.

The rails are cross connected with negative parallel reinforcing cables on a typical spacing of 400m, where installed.

Rail Cross Bonds are considered perfect conductors.

All four rails in each electrical section are considered part of the negative return system.

Earth leakage is treated as a resistance of 50 ohms every 400m.

## 10.2 Newhaven Study

### 10.2.1 Existing Design

The design of the traction power system in the Newhaven / Leith area was established originally for the continuous tram loop continuing westward to Granton and the Roseburn Corridor. The OLE comprises a single contact wire per track, cross-connected at 400m intervals, also connected at those points to parallel underground reinforcing feeder cables. The negative return circuit comprises all four running rails, cross-connected at 400m intervals. Between LWE / NLE and Newhaven (chainage 1.800km), the negative return is supplemented by parallel underground reinforcing feeder cables. Electrical data is included at 10.1.6 above. Traction substations in the section are GVE, NLE, LWE (and CAE for the purposes of this study). A further substation site at Leith Docks (LDE) was inherited from an earlier stage in the project but was deemed to be unnecessary at the Preliminary Design stage.

At the time of the decision to defer Phase 2 (Newhaven to Granton), a reassessment of the design was undertaken, in view of the loss of the electrical link across the gap, with obvious adverse effects on voltage drop and electrical protection, particularly to meet the 'substation out' criteria. That reassessment compared the options of a) reinstating substation LDE, b) increasing the cross section of cable reinforcement, and c) cabling across the Phase 2 gap from GVE to Newhaven. The chosen option was c), which up to now remains the documented design.

The present proposal to separate Phases 1a and 1b (effectively deferring or cancelling 1b) represents a further threat to the traction power supply in the Leith / Newhaven section if GVE were not to be installed with Phase 1a. Under these circumstances, the NLE Outside of Service condition leaves a long electrical overhang from LWE to Newhaven, a section designed to support the heavy 'core' tram service. The design compensation options are essentially the same as for the loss of Phase 2 described above. We have therefore simulated and studied these options:

- Establishment of GVE as a 'Phase 1a' substation, with cable link to Newhaven;
- Deletion of GVE and cable link;
- Additional reinforcing cabling on Phase 1a;
- Addition of substation LDE.

The results are discussed in the next four sections, followed by option selection.

### 10.2.2 Tram positions and loadings NER – CAE.

Runtime Phase 1a – (TIE4D) – 8 trams per hour per direction per service

Having analysed runtime data TIE4D during peak operating periods in the area between NER and CAE. i.e., 8:00am to 9:00am the most onerous operating conditions under the 8 tph per direction Phase 1a timetable is demonstrated at 8:01:06 and 8:08.36 (Approx), then at similar 7.5 minute periods up to 9:00am.

At the time intervals noted there are approximately eight trams in the section between NER and CAE, of which three are accelerating at maximum demand current and critical to the voltage analysis:

Tram (T1) – Approx 50 metres from NER heading towards Ocean Terminal (OCT) Destination HTS. Maximum Demand Current 1,433A.

Tram (T4) – Approx 1,780 metres from NER heading towards Ocean Terminal (OCT) Destination OCT. Maximum Demand Current 1,433A.

Tram (T6) – Approx 2,680 metres from NER heading towards Bernard Street (BES) (Formerly COS). Destination OCT. Maximum Demand Current 1,433A.

The accelerating trams noted above have been carefully developed at the positions noted within the models developed for analysis.

Runtime Phase 1a – (TIE4D) – 12 trams per hour per direction per service.

Having analysed runtime data TIE4D during peak operating periods in the area between NER and CAE. i.e., 8:00am to 9:00am the most onerous operating conditions under the 12 tph per directions Phase 1a timetable is demonstrated at 8:04:40 (Approx), then at similar 5.0 minute periods up to 9:00am.

At the time steps noted, there are approximately eleven trams in the section between NER and CAE, of which five are accelerating at maximum demand current and critical to the voltage analysis and current analysis:

Tram (T1) – Approx 50 metres from NER heading towards Ocean Terminal (OCT) Destination HTS. Maximum Demand Current 1,433A.

Tram (T2) – Approx 650 metres from NER heading towards Newhaven Road (NER) Destination NER. Maximum Demand Current 1,433A.

Tram (T6) – Approx 2,280 metres from NER heading towards Bernard Street (BES) (Formerly COS). Maximum Demand Current 1,433A.

Tram (T7) – Approx 2,650 metres from NER. Leaving Foot of the Walk (FOW). Destination Ocean Terminal (OCT). Maximum Demand Current 1,433A.

Tram (T10) – Approx 4,150 metres from NER. Leaving MacDonald Road (MDR). Destination Edinburgh Airport (AIR). Maximum Demand Current 1,433A.

The accelerating trams noted above have been carefully developed at the positions noted within the models developed for analysis.

### 10.2.3 Reconfiguration Option 1 - Deletion of GVE and cable link

This analysis reviews the concept of removing all Phase 1b components completely; subsequently Traction Sub-Station GVE and DC link to NER from the scheme without further remedial action.

The results of this investigation are developed as output from Model 2 defined in Section 10.1.1. Model ULE90130-SW-CAL-10003, (not included with this report but recorded in DMS), demonstrates the circuit for analysis and observations from the outputs. A summary of prospective Pan and Rail Voltages are defined in the tables below:

Model ULE90130-SW-CAL-10003- Phase 1A – 8 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T1 | T4 | T6 | T1 | T4 | T6 | |
| Normal – All Subs are Feeding Normally | 709.16 | 699.04 | 696.06 | 4.91 | 12.09 | 6.23 | Pan Voltage and Rail Volts acceptable at all trams. |
| LWE is Out of Service | 684.76 | 652.75 | 598.54 | 22.42 | 16.11 | 21.32 | Pan Voltage and Rail Volts are acceptable. |
| NLE is Out of Service | 502.06 | 538.12 | 643.96 | 48.12 | 19.72 | 9.48 | Marginal pass only at T1 for Pan Volts. Too low for design security. Rail volts are becoming significant. |

Discussion

It is clearly demonstrated in the analysis of results from the 8 tph per direction per service model that under **normal** operating conditions or with LWE sub-station out of service that a full timetable can be maintained.

However, if we have a single sub-station outage of NLE Pan Voltage drops to 502V at NER. **This is too close to the minimum acceptable level to be deemed supportable.**

This demonstrates that it is not possible to merely remove the phase 1b components critical to the Traction Power System design and maintain an 8 tph per direction timetable without having to further develop the Traction Power system design within Phase 1a.

The only alternative in this scenario would be to restrict the tram timetable to 6 tph per direction per service.

Further analysis under the twelve trams per hour per direction per service model have not been conducted. It is evident from the 8 tph per direction model that it is not possible to support the ultimate phase 1a service under this operating condition.

10.2.4 Reconfiguration Option 2 - Retention of GVE and DC cable link

This analysis reviews the concept of removing the majority of Phase 1b infrastructure, whilst retaining Traction Sub-Station GVE and DC link to NER. It is important to note that this is the existing design condition minus support to GVE from Tram Granton Mains East 15 TSS (GME).

For the 8 tph per direction enhanced service level, the results of this investigation are developed as output from Model 2 defined in Section 10.1.1. Model ULE90130-SW-CAL-10008, (not included within this report but recorded in DMS), demonstrates the

circuit for analysis and observations from the outputs. A summary of prospective Pan and Rail Volts are defined in the tables below.

For the 12 tph per direction per service level (ultimate), the results of this investigation are developed as output from Model 2 defined in Section 10.1.1. Model ULE90130-SW-CAL-10010, (not included within this report but recorded in DMS), demonstrates the circuit for analysis and observations from the outputs. It is important to note that the core recommendation from the 8 tph per direction model to enhance negative reinforcement between BES and NLE, is included within this model.

A summary of prospective Pan and Rail Volts under 8 tph and 12 tph models are defined in the tables below.

Model ULE90130-SW-CAL-10008 - Phase 1a – 8 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T1 | T4 | T6 | T1 | T4 | T6 | |
| Normal – All Subs are Feeding Normally | 719.01 | 704.39 | 697.81 | 15.17 | 35.15 | 30.50 | Pan Voltage and Rail Volts acceptable at all trams. |
| LWE is Out of Service | 698.99 | 661.50 | 603.93 | 20.44 | 62.69 | 68.18 | Pan Voltage is acceptable. Rail Volts exceeds RSPV2 limit at tram T6. **Consider further reinforcement of negative to bring rail volts down.** |
| NLE is Out of Service | 612.49 | 619.22 | 669.61 | 44.11 | 42.46 | 24.72 | Pan Voltage and Rail Volts acceptable at all trams. |

Model ULE90130-SW-CAL-10009 - Phase 1a – 8 tph per direction per service (Enhanced Negative Reinforcement) – TIE4D

As a development of the above study a further analysis was conducted with the DC link in circuit but with 2000 sq. mm of additional negative reinforcing cables in the area between LWE and NLE. with a view to reducing the potential in the rail demonstrated by LWE out of service above. The results of this investigation are developed as output from Model 2 defined in Section 10.1.1. Model ULE90130-SW-CAL-10009, (not included with this report), demonstrates the circuit for analysis and observations from the outputs. A summary of prospective Pan and Rail Volts are defined in the tables below.

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T1 | T4 | T6 | T1 | T4 | T6 | |
| Normal – All Subs are Feeding Normally | 716.94 | 699.97 | 700.33 | 15.77 | 26.31 | 21.86 | Pan Voltage and Rail Volts acceptable at all trams. |
| LWE is Out of Service | 696.11 | 655.37 | 615.39 | 21.31 | 44.33 | 48.45 | Pan Voltage is acceptable. Rail volts are now acceptable. |
| NLE is Out | 614.78 | 619.96 | 669.25 | 43.47 | 42.30 | 27.38 | Pan Voltage and Rail Volts acceptable at all |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| of Service | | | | | | | trams. |

Model ULE90130-SW-CAL-10010 - Phase 1a – 12 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | | | Rail Volts (Volts) | | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T6 | T7 | T10 | T1 | T2 | T6 | T7 | T10 | |
| Normal – All Subs are Feeding Normally | 698.65 | 687.92 | 685.15 | 706.40 | 715.81 | 20.74 | 20.40 | 24.28 | 20.00 | 11.50 | Pan & Rail Volts acceptable |
| LWE is Out of Service | 678.36 | 664.78 | 608.93 | 652.17 | 646.07 | 26.15 | 27.29 | 46.93 | 46.37 | 20.40 | Pan & Rail Volts acceptable |
| NLE is Out of Service | 554.36 | 539.12 | 630.33 | 666.13 | 688.85 | 59.87 | 59.40 | 37.86 | 27.00 | 6.05 | Pan Voltage acceptable Rail Volts acceptable but at RSPV2 limit. |

Discussion

It is clearly demonstrated in the analysis of results from the 8 tph per direction per service models and the 12 tph per direction service models that under normal operating conditions or with a single sub-station outage, either LWE or NLE, a full timetable can be maintained.

The analysis conducted confirms the earlier decision of SDS to include a DC link of this type when Section 2 was removed from the scheme.

Under the 8 tph per direction model it was noted that with the DC link option that rail voltages at LWE are exceeded when the current design is modelled (See Model ULE90130-SW-CAL-10008). Hence it is necessary to include further reinforcement of negative between LWE and NLE to suppress the voltage at the rails to acceptable levels.

The output of 8tph per direction model ULE90130-SW-CAL-10009 demonstrates that the rail volts are reduced to levels below those recommended by RSP V2 when further negative reinforcement is included in the design.

The output of Model ULE90130-SW-CAL-100010 demonstrates that the ultimate phase 1A service can be accommodated, i.e., 12 tph per direction (24 trams per hour per direction over the core route).

Whilst it is noted that the existing design requires an enhancement to include further negative reinforcement between Bernard Street (BSE) and Tram North Leith Sands TSS (NLE) this will be inclusion of negative reinforcing cables within duct routes for the positive reinforcing cables and already containing spare capacity. Hence the additional costs are restricted to further materials, cable laying and bringing into service cost.

In summary the DC link option provides a technically robust value for money solution in that the infrastructure installed will be required in the final scheme when phase 1b is built.

(Based on the core assumptions that tie intend to build Phase 1b and that the requirement to maintain a full timetable under a single sub-station outage remains).

However, it should be noted that we are distributing the power system some 2.2km past the end of the running tramway at completion of Phase 1a. This obviously requires careful planning within the existing urban environment and also within the context of the future build of Section 2.

It should also be noted that as an existing location, planning and approval applications are already in process for the Tram Granton View Traction Sub-Station (GVE).

10.2.5 Reconfiguration Option 3 - Additional cable reinforcing between LWE/CAE and NLE

This analysis reviews the concept of removing the entire Phase 1b infrastructure including Granton View Traction Sub-Station (GVE) and DC Cable link, whilst providing further parallel cable reinforcement of the OLE and Rails. (This is in addition to the existing design quantities).

The existing design condition has 2,000 sq mm of Aluminium cable reinforcement through the whole section between NER and CAE reinforcing the positive circuit and 2,000 sq. mm of aluminium cable reinforcing the negative circuit (rails) in two pockets NLE to NER and LWE to the Constitution Street tram stop (COS).

This study looks at the analysis of two scenarios with tram movements based on 8 tph per direction per service level:

Model ULE90130-SW-CAL-10004 – The addition of 2,000 sq. mm of reinforcing cables in the negative circuit only between COS and NLE.

Model ULE90130-SW-CAL-10005 – The addition of 2,000 sq. mm of reinforcing cables in the negative circuit between COS and NLE and an additional 1,000 sq. mm of reinforcing cable between CAE and NER (Giving 3,000 sq. mm of reinforcing cables in total for the positive circuit between NER and CAE).

The results of this investigation are developed as output from Model 2 defined in Section 10.1.1. Model ULE90130-SW-CAL-10004 and ULE90130-SW-CAL-10005, (not included with this report), demonstrates the circuits for analysis and observations from the outputs. A summary of prospective Pan and Rail Voltages are defined in the tables below.

A detailed analysis of the ultimate service, 12 tph per direction per service has not been conducted under this design scenario. This is based on the results of modelling conducted at 8 tph per direction per service level. Further details are contained within the discussion section below.

Model ULE90130-SW-CAL-10004 – (Negative Reinforcement Only) Phase 1a – 8 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T1 | T4 | T6 | T1 | T4 | T6 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Normal – All Subs are Feeding Normally | 709.92 | 694.80 | 698.29 | 4.24 | 12.28 | 9.16 | Pan Voltage and Rail Volts acceptable at all trams. |
| LWE is Out of Service | 681.48 | 646.51 | 609.47 | 3.61 | 16.48 | 20.02 | Pan Voltage and Rail Volts are acceptable. |
| NLE is Out of Service | 518.95 | 555.01 | 643,97 | 47.05 | 29.70 | 6.33 | Pan Voltage is lifted due to influence of negative reinforcement. Still close to 500v limit. Rail Volts acceptable at all trams although at T1 they are becoming significant. |

Model ULE90130-SW-CAL-10005 – (Positive and Negative Reinforcement) Phase 1a – 8 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T1 | T4 | T6 | T1 | T4 | T6 | |
| Normal – All Subs are Feeding Normally | 709.41 | 701.96 | 702.15 | 1.25 | 9.33 | 4.23 | Pan Voltage and Rail Volts acceptable at all trams. |
| LWE is Out of Service | 681.75 | 657.14 | 618.81 | 9.46 | 11.69 | 15.99 | Pan Voltage and Rail Volts are acceptable. |
| NLE is Out of Service | 550.55 | 576.66 | 651.86 | 35.04 | 17.68 | 5.71 | Pan Voltage is lifted due to influence of negative and positive reinforcement. Still close to 500v limit. Rail Volts acceptable at all trams. |

Discussion

It is clearly demonstrated in the analysis of results from the 8 tph per direction model with enhanced reinforcement that under normal operating conditions or with a single sub-station outage, either LWE or NLE, a full timetable can be maintained with a small margin on pan voltage at the extremes of the system.

Whilst this provides the opportunity to operate a timetable at 8 tph per direction per service without having to install a DC cable link to GVE or an addition sub-station at LDE, in the view of SDS the system voltages remains fairly close to the limits for comfort to be assured, particularly for Pan voltage.

To investigate the use of parallel reinforcement further, SDS modified model ULE90130-SW-CAL-10004 further to add even more cabling (Model ULE90130-SW-CAL-10005). This produced only marginal improvements over the original results due to the diminished effect of further parallel resistance paths.

SDS believes that relatively minor deviations in the 8 tph per direction per service timetable would cause issues relating to system voltages within this scheme. This can easily be predicted considering that this is a street running area for the tram system where bunching of traffic etc could easily cause deviations from timetable.

Only a qualitative analysis of the 12 trams per hour per direction service operating condition was conducted. Evidence from the 8 tph per direction models suggested it is not supportable.

To further this assumption slightly, using Model ULE90130-SW-CAL-10010 with the GVE DC link switched out, an additional 1,000 sq. mm of parallel reinforcement in the positive

circuit and NLE out of service a brief analysis was conducted. The result of this found that the best case Pan voltage at T1 was in the region of 480V. This is below the minimum acceptable Pan voltage limit and therefore validated the earlier assumption that the Phase 1a Ultimate timetable, 12 tph per direction per service could not be supported under this design condition.

It should be noted that whilst this solution is technically viable, it will only meet the 8 tph per direction per service and in our view even under this operating scenario it is a marginal solution that adds further cost to the scheme in the form of enhanced duct routes and cable requirements.

### 10.2.6 Reconfiguration Option 4 - Additional Sub-Station at Leith Docks LDE

This analysis reviews the concept of removing all of the Phase 1b traction power infrastructure, including Tram Granton View TSS / DC Cable Link and installing a further traction power sub-station in the Leith Docks area at Chainage 1.850km from NER.

At the 8 tph per direction per service, the results of this investigation are developed as output from Model 3 defined in Section 10.1.1. Model ULE90130-SW-CAL-10006, (not included within this report but recorded within DMS), demonstrates the circuit for analysis and observations from the outputs. A summary of prospective Pan and Rail voltages are defined in the tables below:

At the 12 tph per direction per service, the results of this investigation are developed as output from Model 3 defined in Section 10.1.1. Model ULE90130-SW-CAL-10012, (not included within this report but recorded within DMS), demonstrates the circuit for analysis and observations from the outputs. A summary of prospective Pan and Rail voltages for both service levels are defined in the tables below:

Model ULE90130-SW-CAL-10006 - Phase 1a – 8 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T1 | T4 | T6 | T1 | T4 | T6 | |
| Normal – All Subs are Feeding Normally | 727.41 | 732.25 | 721.64 | 1.52 | 2.43 | 3.94 | Pan Voltage and Rail Volts acceptable at all trams. |
| LWE is Out of Service | 721.45 | 720.91 | 680.41 | 4.19 | 2.02 | 11.03 | Pan Voltage and Rail Volts are acceptable. |
| LDE is Out of Service | 709.25 | 697.67 | 695.93 | 5.28 | 11.79 | 6.04 | Pan Voltage and Rail Volts are acceptable. |
| NLE is Out of Service | 642.86 | 677.71 | 710.64 | 5.00 | 23.08 | 5.65 | Pan Voltage and Rail Volts acceptable at all trams. |

Model ULE90130-SW-CAL-10012 - Phase 1a – 12 tph per direction per service – TIE4D

| Operating Condition | Pan Voltage (Volts) | | | | | Rail Volts (Volts) | | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T6 | T7 | T10 | T1 | T2 | T6 | T7 | T10 | |
| Normal – All Subs are Feeding Normally | 703.84 | 698.65 | 704.54 | 707.64 | 725.57 | 9.18 | 6.29 | 0.90 | 0.20 | 3.10 | Pan & Rail Volts acceptable |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LWE is Out of Service | 697.92 | 692.29 | 667.51 | 675.44 | 689.65 | 3.26 | 1.00 | 5.63 | 7.02 | 3.93 | Pan & Rail Volts acceptable |
| LDE is Out of Service | 686.93 | 680.52 | 665.46 | 684.34 | 711.77 | 4.03 | 2.34 | 6.19 | 2.46 | 7.20 | Pan & Rail Volts acceptable |
| NLE is Out of Service | 559.32 | 558.21 | 682.52 | 671.72 | 714.73 | 52.60 | 45.70 | 12.51 | 15.68 | 23.88 | Pan Volts acceptable . Rail Volts are becoming significant. |

Discussion

It is clearly demonstrated in the analysis of results from the 8 tph per direction per service model and the 12 tph per direction model that under normal operating conditions or with a single sub-station outage, either LWE, LDE or NLE, a full timetable can be maintained with the introduction of the new sub-station at Leith Docks.

In principle this is due to the reduced feed distances under single sub-station outage conditions. An example being when NLE is Out Of Service where under the existing configuration the single end feed distance is approaching 3.034km, whereas with LDE in circuit this is reduced to 1.854km.

Of the system re-configuration options considered by removing Phase 1b, the addition of a further sub-station in the Leith Docks area supports the system voltage voltages in the most efficient manner, whilst also reducing the load currents in the track feeder circuits. (Shorter feed distances and fewer trams in each electrical section).

Technically it is the best solution.

Whilst this solution is technically the best performing solution to resolve known issues with Pan voltage in the NER area under Phase 1b removal, it adds a significant cost to the system. This is somewhere in the region of £1M and only provides significant benefit to the system whilst the section to NER is single end fed under the proposals for Phase 1a only. When the link is closed at completion of Phase 1b and double end feeding is introduced to Tram Granton View TSS (GVE), we then have a very much over-specified system.

10.2.7 Selection of Option

The aspiration of **tie** is to run three levels of service following construction of Phase 1a: an initial service of 6 tph per direction per service (12 tph per direction over core route), an enhanced service of 8 tph per direction per service (16 tph per direction over core route) and an Ultimate Service of 12 tph per direction (24 tph per direction over the core route).

Understanding the service levels required we can place each of the Phase 1a – 1b separation options considered in 10.2.3 to10.2.6 within the context of the service levels:

| Separation Option | Ability to Support Phase 1A Service Pattern | | | Comment |
|---|---|---|---|---|
| | Initial | Enhanced | Ultimate | |

| | Service 6 tph pd | Service 8 tph pd | Service 12 tph pd | |
|---|---|---|---|---|
| Deletion of Cable Link to GVE Only. (10.2.3) | YES | NO | NO | When evaluated against 8 tph pd timetable pan voltage at NER is at minimum levels. **This option will not support the enhanced (8tph pd ps) or ultimate (12tph pd ps) services.** |
| Retention of Cable Link to GVE (10.2.4) | YES | YES | YES | Additional negative reinforcement is required to surpress rail volts in this solution. **However this option will support all levels of service anticipated at Phase 1A with only limited modification to the existing Traction Power design.** |
| Deletion of Cable Link to GVE and addition further Cable Reinforcement CAE – NER area (10.2.5) | YES | YES* | NO | Allowing for 3,000 sq mm of aluminium cable reinforcing the OLE and 2,000 sq. mm re-inforcing the Rails between CAE and NER the Enhanced service can be supported. However it should be carefully noted that Pan volts remains close to the low limit and SDS feel that slight variations in service pattern could unduly influence the Traction Power Supply. |
| New Traction Sub-Station and Leith Docks (LDE) (10.2.6) | YES | YES | YES | Adding a further Traction Sub-Station at Leith Docks provides the best performance re-configuration option regards Pan Volts, Rail Volts and circuit loading. This option will support all levels of service required. However a design does not exist for LDE currently and there will be a significant additional cost in time and money to implement. |

10.2.8 * - Careful attention to comment required.

Of the options presented it remains the opinion of SDS that implementing the small amount of Phase 1b Traction Power infrastructure required to install GVE and retain the proposed DC link remains the best compromise between performance, cost and time for the Edinburgh Tram Network.

It is acknowledged that this option does not give the same technical performance benefit that you achieve with the implementation of a new sub-station at Leith Docks however the performance promised is adequate and in line with delivering all levels of service up to 12 trams per hour per direction per service required under the ultimate service pattern. GVE is an absolute requirement under Phase 1b and hence the investment in this infrastructure is required in the long term and allows tie to meet the service pattern aspiration under Phase 1a at minimal additional cost over and above the existing design.

The principal difficulty with this option that SDS fully acknowledge is that essentially under this option we are extending the power infrastructure 2.2km past the end of the running tramway at Phase 1a. This may present particular operational and maintenance based issues that **tie** should carefully consider if selecting the option.

The addition of a new sub-station in the Leith Docks area as demonstrated through this report offers a very robust solution that outperforms all of the re-configuration options

considered. However, this comes at a significant additional cost to the project (£500k - £1M Approx) for the benefit of maintaining a full timetable under an adjacent sub-station outage only. When double end feeding is introduced, the link to GVE being an example, it can be demonstrated that the system performs well enough not to require LDE. If we therefore, consider a final system with Phase 1a built (including LDE), Phase 1b built and possibly Phase 2, we would have a system that is overly robust and implemented only to meet the requirements of build sequencing.

Options that consider removing double end feeding via GVE or do not consider the inclusion of an additional sub-station in the Leith Docks area are attractive from the perspective of reducing capital expenditure at Phase 1a. However, the most significant issue regards such options is that they struggle to allow the desired service patterns to be achieved. If we consider the additional reinforcing example, a significant amount of has to be introduced to allow the Phase 1a enhanced service (8 tph per direction) to be an option. Under this feeding condition the Power Supply remains brittle.

An important issue here is the level of service that **tie** require under Out of Service operating conditions. In all options under normal feeding it is the view of SDS that the Ultimate service* could be accommodated. If **tie** were willing to consider a relaxation of Out of Service operating conditions then the options that involve total curtailment of Phase 1b infrastructure (Option 1) or curtailment of Phase 1b infrastructure and additional reinforcement (Option 3), become more viable.

* - It should be carefully noted that further validation work would be required to confirm this for the options that do not involve a DC link to GVE or the addition of a sub-station at Leith Docks. Evaluation of Phase 1b removal option and Phase 1b removal option with additional reinforcement option has not been evaluated at the 12 tph per direction per service level.

In considering the re-configuration options evaluated by this study and based on the two core assumptions that Phase 1b will be built and that a full timetable is to be maintained under Out of Service operating conditions, we would rank the solutions in order of preference from 1 to 4 as follows:

Retain DC Link to GVE – Retain current proposal to install infrastructure for Tram Granton View TSS and Provided DC Cable Link between GVE and Newhaven Road Tram stop (NER). Add 2,000 sq. mm of Negative Reinforcing cables between BES (formerly COS) and Tram North Leith Sands TSS (NLE).

Sub-Station at Leith Docks – Introduce new sub-station at approximately 1.850km from NER. (Notionally LDE Sub-Station). Further review removal of negative reinforcement between BES (formerly COS) and LWE.

Remove DC Link to GVE and add further Parallel reinforcement CAE – NER – Remove DC Link option to GVE and GVE from design. Enhance OLE reinforcement design CAE – NER by adding a further 1,000 sq. mm of aluminium reinforcement in parallel with existing 2,000 sq. mm of reinforcement. (3,000 sq mm total). Add 2,000 sq mm of negative reinforcement to the existing design in two areas. Between Tram Cathedral Lane TSS (CAE) and Tram Leith Walk 163 TSS (LWE); Also Bernard Street (BES) to Tram North Leith Sands TSS (NLE). (Note, there is an existing pocket of reinforcement between LWE and BES).

Remove DC Link Only – Remove DC link and GVE option from scheme design.

Two further general points should be noted, both of which are beyond the scope of this study:

Relaxation of the 'full service with any one substation out' specification clause, through accepting temporary operational restrictions in the areas of 'end of line' substations, would result in modified designs which would yield significant infrastructure capital cost savings; and

Energy costs have risen about 50% in the past 18 months. Further attention should be paid to optimising energy efficiency through infrastructure design, avoidance of the application of 'all out' running timetables (10% time relaxation can yield 50% energy saving), and consideration of the settlement of energy bills by the Operator.

## 10.3 Roseburn Junction Study

### 10.3.1 Existing design

The design of the traction power system in the Roseburn Junction area was established to provide a robust and operationally flexible feed for both the route to Edinburgh Airport and the route via the Roseburn Corridor to Granton. The OLE comprises a single contact wire per track, cross-connected at 400m intervals, also connected at those points to four parallel underground reinforcing feeder cables (2,000 sq. mm csa of stranded aluminium cabling). The negative return circuit comprises all four running rails, cross-connected at 400m intervals. There are no negative reinforcing feeder cables in this area. Electrical data are included at 10.1.6 above. Traction substations in the section are HTE, JDE, SGE (and CAE and BDE for the purposes of this study). A track paralleling hut (Russell Road TPH) is included at Roseburn Junction to provide mutual electrical support between the two branch routes and optimise operational flexibility during disrupted service conditions. This TPH is designed to be upgraded to a full traction substation, to meet future service capacity needs. Its substation name would then be 'Tram Russell Road 22' (RRE).

The present proposal to separate Phases 1a and 1b (effectively deferring or cancelling 1b) has implications on the design of the traction power supply in the Roseburn Junction area, as SGE would not be available to contribute to Phase 1a operation past the missing junction. Under these circumstances, the HTE Out of Service condition leaves a long electrical section from CAE to JDE, and the JDE Out of Service condition leaves a long section from CAE to BDE, the section as far as HTE siding being designed to support the heavy 'core' tram service. Furthermore, the need for Russell Road TPH may be doubtful if the junction and Phase 1b were not built. There are therefore, two design compensation options which we have simulated and studied:

Retention of RRE TPH but without SGE feed (SGE included as a reference condition only);

Postponement / deletion of RRE.

The results are discussed in the next two sections, followed by the option selection.

On the original scheme, the RRE TPH was positioned strategically at Roseburn Junction to meet the design criteria and to support the three legs at the junction: HTE, JDE and SGE.

The scheme's design criteria are on the basis of multiple feed to the track, (this stabilises voltages) where loss of one TSS does not have an adverse effect on the full operation of the train time table. With TSS SGE (South Groathill Av) now not available, a model was developed where the SGE TSS was studied for its impact on the rest of the network with BDE, JDE, RRE, HTE, and CAE.

The model demonstrated the position of trams and the loading along the track JDE-CAE. The model demonstrated that there was some impact of the omission of GSE TSS on the junction although it helped the pen voltage and rail voltages at RRE TPH and of the tracks at the Roseburn junction, the revised scheme will cope with the omission of the SGE TSS. For this train graphs were analysed for identifying accelerating trams and their location within the system whilst drawing maximum load current. The graph TIED 4D - 12 tph per direction was most onerous and therefore, the model looked at 12 tph per direction, which showed two distinct areas where the density of trains varied. In the core zone the tram density was 12 tph and in the non-core area, the density was substantially less.

### 10.3.2 Tram positions and loadings BDE - CAE

Tram graphs (TIE4D 12 tph per direction) was analysed for identifying accelerating trams and their location within the system whilst drawing maximum load current.

Closer analysis indicated that in the rail section west of Haymarket TSS is less onerous, whilst the track east of Haymarket (the core section) is the most onerous.

A model was developed from the analysis of the timetable (SDS graph 2, TIED4D 12 tph per direction) with the data extrapolated from the chainage, between the hour of 08:00 and 09:00, and at approx 08:05:30 and subsequently 5 minutes intervals thereafter, the congestion of trams are as follows:

Tram T2 at approx 9,988m chainage, (450m past JDE), destination BAR, the tram is coasting/ decelerating.

Tram T3 at approx 7,387m chainage, (450m past RRE), destination MUR, the tram is accelerating.

Tram T6 at approx 7,069m chainage, (150m from HAY), destination SHP, and the tram is coasting/ decelerating.

### 10.3.3 Reconfiguration Options – Removal or Retention of RRE

Using the above data, a model was developed where the SGE TSS was studied for its impact on the rest of the network with BDE, JDE, RRE, HTE, and CAE. The model demonstrated that there was no appreciable impact of the omission of GSE TSS on the junction. (The results of this analysis are demonstrated in Model ULE90130-SW-CAL-10013).

Further study was carried out to see the impact removing Tram Russell Road TPH (RRE) entirely from the Traction Power Supply at Phase 1a.

For both models scenarios considering adjoining TSS Out of Service; one with JDE Out of Service and another with HTE Out of Service were considered.

The results of these investigations are developed as output from Models 3 and 4 defined in Section 10.1.5. Model ULE90130-SW-CAL-100013 and ULE90130-SW-CAL-10014, (not included with this report but recorded in DMS), demonstrates the circuits for analysis and observations from the outputs. A summary of prospective Pan and Rail voltages are defined in the tables below.

Model ULE90130-SW-CAL-100013 - Phase 1a – 12 tph per direction per service – TIE4D – SGE Removed from scheme, Tram Russell Road TPH retained.

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T2 | T3 | T6 | T2 | T3 | T6 | |
| Normal – All Subs are Feeding Normally | 749.84 | 732.13 | 726.04 | 12.84 | 16.70 | 16.36 | Pan Voltage and Rail Volts acceptable at all trams. |
| JDE is Out of Service | 726.23 | 724.63 | 720.26 | 4.19 | 20.85 | 19.13 | Pan Voltage and Rail Volts are acceptable. |
| HTE is Out of Service | 741.17 | 6932.78 | 687.12 | 18.76 | 55.92 | 55.86 | Pan Voltage acceptable. Rail Voltages are becoming significantly high. |

Model ULE90130-SW-CAL-100014 - Phase 1a – 12 tph per direction per service – TIE4D – SGE Removed and Tram Russell Road TPH removed.

| Operating Condition | Pan Voltage (Volts) | | | Rail Volts (Volts) | | | Notes |
|---|---|---|---|---|---|---|---|
| | T2 | T3 | T6 | T2 | T3 | T6 | |
| Normal – All Subs are Feeding Normally | 749.84 | 732.13 | 726.04 | 12.84 | 16.70 | 16.36 | Pan Voltage and Rail Volts acceptable at all trams. |
| JDE is Out of Service | 726.23 | 724.63 | 720.26 | 4.19 | 20.85 | 19.13 | Pan Voltage and Rail Volts are acceptable. |
| HTE is Out of Service | 741.17 | 6932.78 | 687.12 | 18.76 | 55.92 | 55.86 | Pan Voltage acceptable. Rail Volts are becoming significantly high. |

Discussion

It is clearly demonstrated in the analysis of results from the 12 tph per direction per service model under normal operating conditions with SGE removed and with a single sub-station outage either JDE or HTE Out of Service; a full timetable can be maintained.

As the system with SGE removed supports the Ultimate Phase 1a timetable, it is not necessary to review lower density models in the form of 8 tph per direction per service (Enhanced) or 6tph per direction per service (Initial).

The results of Model ULE90130-SW-CAL-10013 clearly demonstrate that the impact of removing SGE and the further sub-stations along Section 3 does not affect the power supply along Sections 2 and 5 sufficiently enough to force a significant re-configuration of the traction power system design in this area.

It should however be noted that the results of this model demonstrate that the rail potentials approach the limits set out by RSP2 when Tram Haymarket Terrace 01 TSS (HTE) is out of service. In reviewing this we are of the opinion that consideration of negative reinforcement will obviously improve this, however the margin is sufficient to postpone consideration of this until further PowerPlan simulation is conducted against a full and final Phase 1a timetable.

As a follow up to the initial modelling activity we further reviewed the impact of removing RRE completely via Model ULE90130-SW-CAL-10014. As anticipated the changes in system voltages in comparison to Model ULE90130-SW-CAL-10013 are minimal and demonstrate that removing Russell Road TPH from the Phase 1a construction package is a viable option should **tie** wish to consider it.

10.3.4 Selection of Option

The results of this modelling exercise have clearly demonstrated that the removal of Phase 1b from the initial construction package, including the removal of Tram South Groathill Avenue TSS (SGE) does not impact the traction power supply in Section 2 and 5 to the extent that a re-configuration of traction power supply is required in this area. Traction Pan voltages remain within the limits set out by BS EN and Rail Potentials remain within the limits set out by RSP2 under all Out of Service Conditions analysed.

Further analysis of the power supply in the Section 1, 2 and 5 areas between Tram Cathedral Lane TSS (CAE) and Tram Bankhead Drive TSS (BDE) has also demonstrated that Tram Russell Road TPH can also be safely removed from the Phase 1a package. Whilst this seems to be a very effective value engineering option is should be carefully noted that Tram Russell Road TPH is essential to the Traction Power Supply when Phase 1b is built.

On balance we feel that **tie** should consider removing it from the Phase 1a construction package if Phase 1b is to follow at a later date. However, **tie** should carefully consider two key issues in removing RRE from the Phase 1a package:

OLE Configuration and Electrical Sectioning – Removing Russell Road TPH from Phase 1a would require that a two stage OLE design is developed. The current design which services Phase 1b completion effectively, demonstrates RRE in circuit with a number of electrical sectioning and insulation points included in the scheme. If RRE is removed the delta implementation is postponed until Phase 1b a much simpler insulation and sectioning scheme is required at Phase 1a. The Phase 1a design would need to be carefully considered so that it facilitated the Phase 1b development, i.e., positioning of feeder poles, temporary anchors and bypass jumpers at insulation points.

Site Location and Protection Of – As all will note, a site has been identified for Tram Russell Road TPH and as such planning and approvals for it is in progress. As this site is essential to the build of the Phase 1b infrastructure we would recommend that

planning and approvals continues for this site and that **tie** place every effort to protect the location.

**tie** should carefully consider the option to retain or remove Tram Russell Road TPH from the scheme and advise us accordingly.

Two further general points should be noted, both of which are beyond the scope of this study:

Relaxation of the 'full service with any one substation out' specification clause, through accepting temporary operational restrictions in the areas of 'end of line' substations, would result in modified designs which would yield significant infrastructure capital cost savings; and

Energy costs have risen about 50% in the past 18 months. Further attention should be paid to optimising energy efficiency through infrastructure design, avoidance of the application of 'all out' running timetables (10% time relaxation can yield 50% energy saving), and consideration of the settlement of energy bills by the Operator.

## 10.4 Electrical Operations Implications

### 10.4.1 Electrical nomenclature application

The electrical nomenclature system approved for application on the Edinburgh Tram Network is described in SDS Doc. Ref: ULE90130-SW-SW-REP-00196 (HB Ref: UKPB1-#23098). This follows the established system of three-letter abbreviations covering all tram stops, substations and other operating locations. The system can accommodate any of the changes proposed in this report without any additions or revision.

### 10.4.2 Substations

Names and abbreviations of traction substations have been developed in conjunction with Scottish Power, ensuring that these satisfy the reference criteria of both Scottish Power and the Edinburgh Tram Network; at the time of drafting this report, these are agreed to be as follows:

| Substation | Abbreviation | Switchgroup Identifier No. |
|---|---|---|
| Tram **R**ussell Road 22 TPH | RRE | 02 |
| Tram **S**outh Groathill Avenue SS | SGE | 04 |
| Tram Granton **M**ains East 15 SS | GME | 06 |
| Tram Granton **V**iew SS | GVE | 08 |
| Tram **N**orth Leith Sands SS | NLE | 10 |
| Tram **L**eith Walk 163 SS | LWE | 12 |
| Tram **C**athedral Lane SS | CAE | 14 |
| Tram **H**aymarket Terrace 1 SS | HTE | 16 |
| Tram **J**enners Depository SS | JDE | 18 |
| Tram **B**ankhead Drive SS | BDE | 20 |
| Tram **G**ogar Depot SS | GDE | 22 |
| Tram **E**astfield Road SS | ERE | 24 |

| | | |
|---|---|---|
| (Note: The **bold** letters define the OLE section ref.) | | |

The nomenclature system can cope with the deletion, addition, relocating or renaming of substations as currently devised.

Relevant to this study is the option of adding a substation at Leith Docks (LDE). If this option were to proceed, discussions with Scottish Power would include agreement on joint naming of this substation. SP will use the location's street name + nearest house number, with the prefix 'Tram'. A key letter in the name will determine the two-letter identifiers for the new OLE sections and OLE structures in those sections. Before those discussions, the substation could be added to the table above as:

| | | |
|---|---|---|
| Tram Leith Docks SS | LDE | 09 |

10.4.3 Overhead line structures and electrical sections

The identifier system used for any OLE support structure (be it mast, pole, underbridge arm or building fixing) provides two pieces of essential information to the operator, controller and maintainer:

The electrical section

Operational Chainage (in km and m) from the established datum.

The electrical section is designated by two letters - the key letters of the substations feeding it. For example, the electrical section between Tram North Leith Sands and Tram Leith Walk 163 is NL, and all structures supporting the OLE on this section will carry these letters. As 'in' and 'out' tracks are cross-connected and fed from common circuit breakers, the electrical sections take initial letters in direction of increasing chainage.

Where a sub-section is fed as a 'spur' off a main section, its OLE supports carry the suffix X, for example NLX.

In the case of the last substation on a route tail end feeding to the end of the line, a reference letter for the terminal station is used.

At feeder locations, where two sections abut, the structure carries a three-letter reference, relating to all three substations. For example, the feeder location at Tram Leith Walk 163 is designated NLC, as the next substations is Tram Cathedral Lane.

The chainage is given by two digits (km) and three digits (m) beneath.

An example of a structure number in Constitution Street (fed from Tram North Leith Sands and Tram Leith Walk 163) is:

**NL**

**01**

**234**

Where sections are divided into sub-sections by section isolators, the sub-sections are identified by a lower case letter in brackets, e.g., BC(a), BC(b) etc. Sub-section references are used only in Isolation Documents, Permits-to-Work etc.

Unless any OLE structures have to be relocated due to the separation of phases, the only revisions to OLE structure numbers and electrical section references would be due to revised substation locations or names.

10.4.4 Main sectioning

For the Newhaven study the options considered would have the following effects on main sectioning:

| | |
|---|---|
| Retention of GVE: | No change to main sectioning. |
| Additional reinforcing cabling: | No change to main sectioning. |
| Addition of LDE: | NL section would be split into NX and XL sections (X to be devised). |

For the Roseburn Junction study the options considered would have the following effects on main sectioning:

| | |
|---|---|
| Retention of RRE: | No change to main sectioning. |
| Postponement of RRE: | HR and RJ sections would be combined to form HJ section. |

10.4.5 Sub-sectioning

For the Newhaven study the options considered would have the following effects on sub-sectioning:

| | |
|---|---|
| Retention of GVE: | No change to sub-sectioning. |
| Additional reinforcing cabling: | No change to sub-sectioning. |
| Addition of LDE: | The existing section isolator DS4NL would be replaced by new feeder point NXL. Sub-section NL(c) would become XL and NL(d) would become NL(c) (X to be devised), plus associated changed switchgear references. |

For the Roseburn Junction study the options considered would have the following effects on sub-sectioning:

| | |
|---|---|
| Retention of RRE: | No change to sub-sectioning. |
| Postponement of RRE: | HRJ feeder point abandoned. Isolator DS3HRX1 retained for sub-sectioning west of Haymarket siding, but re-numbered DS3HJ. Sub-sections HR(a), HR(b), |

RJ would become HJ(a), HJ(b), HJ(c) respectively. Haymarket Siding would become HJ(d), and its isolator DS4HJX.

## 10.5 Protection Setting Review

### 10.5.1 General

We have reviewed the protection setting report ULE90130-SW-REP-00388 V1 in respect of the possible changes outlined in this report and confirm that there are no protection issues which would give cause for choosing one option in particular for feeding the trams over the others. To calculate the protection settings for all the circuit breakers for the permutation of options at this stage is unrealistic and should be deferred until a power feeding option has been selected. It is appropriate to offer the following notes on how the alternative feeding options will affect the protection settings at the circuit breakers facing the sections to be changed as described elsewhere in this report.

### 10.5.2 Retaining GVE substation

Retaining GVE substation will ensure double end feeding of all electrical sections at the Newhaven Road end of the tram system under all legitimate feeding conditions. This double end feeding is of great benefit in ensuring a high fault / load discrimination for protection of the system without excessive cable reinforcing of the OLE. The protection setting is a function of feeding distance to the next substation and fixed by geography, but the tram loading is shared, (though not simplistically halved) between the two feeding circuit breakers in the substations at either end of the section, and hence is dramatically reduced.

### 10.5.3 Eliminating GVE traction substation

Eliminating GVE traction substation means single end feeding the last section of the system from LWE under conditions of NLE substation out of service. Thus all the tram loads are fed via a single circuit breaker whose maximum setting is fixed by geographical distance and the variable of 'cross section of OLE reinforcement'. This cross section would need to be increased to support the pantograph voltage of the trams under the greater service loadings projected, as this report details, and this will benefit the maximum protection settings possible.

### 10.5.4 Adding LDE substation

Adding LDE traction substation will only be done if GVE is eliminated. It will be approximately mid - way between LWE and NLE. This will simply improve all the protection settings possible under normal feeding conditions and with CAE out of service. Under the condition of NLE out of service LDE will become the end traction substation and single end feed an overhang to NRD, but the overhang will only be half that when LWE acts as the end substation with NLE out of service. Halving the distance and without increasing the OLE support cables practically doubles the maximum protection settings possible for the circuit breaker feeding and by halving the number of trams in section reduces the loading seen by the same circuit breaker. This double advantage is

reflected in improved pantograph voltages and reduced rail potentials as well as fault / load discrimination.

10.5.5 Eliminating RRE and SGE substation

Postponing the Roseburn corridor route removes both the tram loading associated with it and also the contribution of SGE traction substation into the Airport line, particularly when Haymarket (HTE) traction substation is out of service. Having removed this contribution it makes almost no difference to protection issues, whether RRE is in service or not. This is because RRE is interposed into what would be a normally acceptable feeding section of 2.3 km between HTE and JDE. The OLE between JDE, SGE and HTE had already been specified as heavily supported by a parallel cable feeder, so that either SGE or HTE could support the long feeding section between JDE and GDE in the event of JDE being out of service. Even with HTE out of service the extended feeding section double end fed is a modest 5km long with heavy parallel reinforcing over the whole distance.

Changes to the protection settings for JDE looking towards HTE will have only minor revision. HTE looking towards JDE will now fall more into line with HTE looking towards CAE.

## 10.6 Related Document Review

10.6.1 Power Feeding and Sectioning Diagrams

This set of three drawings shows the power feeding and sectioning arrangements for the 750Vdc system:

ULE90130-SW-OLE-00007 – Sections 1, 2 and 3.

ULE90130-SW-OLE-00008 – Sections 5 and 7.

ULE90130-SW-OLE-00009 – Section 6 (Gogar Depot).

Diagrams ULE90130-SW-OLE-00008 and ULE90130-SW-OLE-00009 are not affected by this separation exercise.

Current DC feeding and sectioning diagram ULE90130-SW-OLE-00007 is the diagram most affected by the separation of Phase 1a and 1b. Essentially this diagram reflects the current design of the Traction Power Supply to satisfy Phase 1a and 1b implementation when both phases are brought into service coincidentally.

It is our view that this diagram will need to be split into two versions if Phases 1a and 1b are separated. One version would represent the Traction Power Supply design at completion of Phase 1a and a second would detail the Traction Power supplies design at completion of Phase 1b.

Once **tie** has considered the options and preferred solutions presented and has subsequently provided clear instruction to us as to which option to develop, the new diagrams will aid the development of the detailed design of the Phase 1a and Phase 1b traction power supply systems.

10.6.2 Substation Equipment Specification

The Traction power equipment for the Edinburgh Tram Network is specified by document titled and referenced as 'ULE90130-SW-SW-SPN-00061 – Traction Power Equipment Specification'.

As the document in principle mandates the specification of equipment contained within the Traction Sub-Stations changes to this document, subject to Phase 1a and 1b separation are limited to the amendments as follows:

Section 3.1.2 – Switchgear Compartment Configuration – Amendment to clauses for RRE.

Section 4.1 – Power Systems Design Principles – Table of Traction Sub-Stations for phase breakdown.

Schedule A – Bill of Quantities for Primary Traction Power Equipment – Possible addition of LDE if instructed by tie.

Appendix A – DC Feeding and Sectioning Diagrams – Addition of phase split version of ULE90130-SW-OLE-00007.

These amendments are considered minor and do not involve a much design work in their execution.

10.6.3 Substation Single Line Diagrams

SDS has developed a series of single line diagrams for the Traction Sub-Stations on the ETN. The Series of diagrams is ULE90130-SW-TSU-00001 to ULE90130-SW-TSU-00015.

On the assumption that Phase 1b is built, all of the existing drawings in the series will be unaffected.

Dependent upon the option that is instructed by tie a further diagram pursuant to a new Traction Sub-station at Leith Docks (LDE) may be required. This would be numbered as diagram ULE90130-SW-TSU-00016, if required.

10.6.4 Cable Schedules

The Edinburgh Tram Network cable schedules appear as Appendix 1 to the Tramway Cable Co-ordination – Working Paper – ULE90130-SW-REP-00210. This proposes a cable referencing system for development by the InfraCo, in which blocks of four-digit reference numbers are allocated to the various types and functions of cabling. Generic cable types are as follows:-

1000-Series: HV Supply Cables

2000-Series: 750Vdc Positive Feeder Cables

3000-Series: 750Vdc Negative Feeder Cables

4000-Series: Stray Current Collector Cables

5000-Series: LV Supply Cables (400/230Vac)

6000-Series: Sub Station Inter-Tripping and Mass Tripping Cables

7000-Series: Telecommunications Multi-Pair Cables

8000-Series: Optical Fibre Network Cables

Each cable series is developed to identify individual cable runs, routes and associated requirements including cable termination. These details are provided on schedules subordinate to the master cable schedule and their purpose is to aid procurement, installation, testing and commissioning and the eventual operation and maintenance, including changes and extensions to the network.

From the traction power system reference design, the above scheduling system under series 1000, 2000, 3000, 4000 and 6000 series have been populated with reference numbers for individual traction power cables. The number system is highly adaptable, and can readily cope with any of the phase-splitting options studied in this report. As none of the selected options involve additional substations, there is no need to create new blocks of cable numbers. The options involving alterations to reinforcing cable arrangements would affect the 26XX and 36XX series (for positive and negative cables respectively). Any other options involve only programming of cabling works rather than cabling design changes, so would not affect the schedules.

The allocation of cable schedule numbers is driven by the Power Feeding and Sectioning diagrams (see 10.6.1 above). These will be revised following acceptance of the recommendations of this report, and the Cable Schedules will be revised accordingly.

It is important to note that the Cable Routes and Ducting design for the ETN has been developed from the HV Power Cable Schedules which in turn were developed from DC Feeding and Sectioning Diagrams ULE90130-SW-OLE-00007 to 00009 V4. Amendments of the nature proposed by this report for HV power cabling infrastructure and introduced within DC feeding and sectioning diagrams and cable schedules will also need to be developed into the cable routes and ducting design.

### 10.6.5 Scottish Power HV supplies

As part of the Traction Power remit for the Edinburgh Tram Network project, PB held a series of discussions with the Distribution Network Operator (DNO) on the provision of high voltage (HV) power supplies, through the Preliminary and Detailed Design phases of its work. The position is summarised in SDS Doc: High Voltage Interfaces with Scottish Power – Position Report – ULE90130-SW-REP-00379. Once the Preliminary Design phase had reached the point where draft locations and ratings of traction substations were known, PB made an approach to **tie** to arrange a preliminary meeting with Scottish Power. The first meeting took place on 2nd May 2006. Progress over the following eight months was excellent:

| Date | Meeting | Location |
|---|---|---|
| 2 May 2006 | Meeting No.1 | Halcrow, Edinburgh |

| | | |
|---|---|---|
| 20 June 2006 | Meeting No.2 | **tie**, Haymarket |
| 25 July 2006 | Meeting No.3 | **tie**, Haymarket |
| 14 August 2006 | Internal **tie** / SDS meeting | **tie**, Haymarket |
| 24 August 2006 | Meeting No.4 | SP, Cumbernauld |
| 17 October 2006 | Meeting No.5 | **tie**, Haymarket |
| 1 November 2006 | Substation visits / naming | Sites |
| 5 December 2006 | Meeting No.6 | **tie**, Haymarket |
| 16 January 2007 | Meeting No.7 | SP, Bellshill |
| 6 February 2007 | Visit to Stagecoach Supertram | Nunnery Depot, Sheffield |

Meetings 4 and 7 were held at Scottish Power offices and took the form of Technical Workshops, in order to facilitate detailed technical discussions with Scottish Power's Heads of Profession in respect of their specific subjects (e.g. Standards, Earthing, Power Quality, Stray Current etc.). The meeting held on 1st November 2006 took the form of a joint inspection visit to each of the prospective traction substation sites, partly for familiarisation, but primarily to discuss and agree joint naming of the substations between ETN and Scottish Power.

At no stage of these discussions was the possibility declared that parts of the initially authorised route may be separated from other sections, it being assumed that substations would be built and commissioned sequentially as route construction extended away from Gogar Depot. If separation is adopted, further discussions should take place with Scottish Power explaining the consequences on substation construction and commissioning, from the viewpoints of both the construction programme and of the phased build-up of traction load.

If the preferred separation strategy recommended in this report were adopted, the traction substation list shown in Section 10.4.2 would split thus:

| Substation | Abbreviation | Switchgroup Identifier No. |
|---|---|---|
| **Phase 1a:** | | |
| Tram Granton **V**iew SS | GVE | 08 |
| Tram **N**orth Leith Sands SS | NLE | 10 |
| Tram **L**eith Walk 163 SS | LWE | 12 |
| Tram **C**athedral Lane SS | CAE | 14 |
| Tram **H**aymarket Terrace 1 SS | HTE | 16 |
| Tram **J**enners Depository SS | JDE | 18 |
| Tram **B**ankhead Drive SS | BDE | 20 |
| Tram **G**ogar Depot SS | GDE | 22 |
| Tram **E**astfield Road SS | ERE | 24 |
| | | |
| **Phase 1b:** | | |
| Tram **R**ussell Road 22 TPH (future SS) | RRE | 02 |
| Tram **S**outh Groathill Avenue SS | SGE | 04 |
| Tram Granton **M**ains East 15 SS | GME | 06 |

The consequences of this split are only of a programming and commercial nature; there are no additional technical issues arising.

It is also important to note that as a result of this study and based on the separation options selected by **tie** could potentially require fresh negotiations, both technical and procurement based, for a new Traction Sub-Station at Leith Docks. (Tram Leith Docks TSS (LDE)).

The implications on **tie**'s delivery programme for the network and the costs associated with a new sub-station at LDE should not be underestimated and would need to be pursued as soon as possible if this option were selected.

10.6.6 Stray Current Working Party

The Stray Current Working Party (SCWP) is the co-operative forum set up between **tie** and the Utilities to manage the process of controlling dc stray currents emanating from the Edinburgh Tram Network and mitigating their corrosive effects on buried metallic plant. The terms of reference of the SCWP are outlined in the Code of Practice for Stray Current Corrosion Control (or associated Agreement) and are in the process of being agreed within the Party. The primary control measure is embodied in the design and specification of the traction power system and return rails of the track; this is aimed at minimizing the levels of stray current flowing in the earth and buried metalwork. The Code of Practice sets acceptability interference criteria on the levels of corrosion potentials of buried metalwork (based on best UK practice and EN Standards) and mandates the undertaking of corrosion potential testing on selected Utility Test Sites, both before Tram operation, to assess the quiescent interference position, and then after the system is operational to assess the additional effects of Tram operation.

To date the SCWP has met three times, and we are now starting the identification of Utilities' Test Sites. Inevitably some of these will be located on Phase 1a and some on 1b. Members of the SCWP are already aware of the possibility of separation of phases, and will be kept up to date as the programme unfolds.

One of the criteria we considered when evaluating the various solution options in the Leith-Newhaven area was the control of track voltage and the associated control of stray current. The preferred option ensures that the 'Phase 1a only' condition is no more onerous than the 'Phase 1a+1b' condition; this would not have been the case for the cable-reinforcement option. Thus the splitting of the Phases should have only test programming effects rather than interference level change effects in this area.

The same criteria apply at the Roseburn end of Phase 1b, but the outcome will be a little different. Here, operation of Phase 1a on its own will rely on feeding from HTE and JDE, without contributory feeds from SGE. Without Phase 1b, the track voltage excursions in the Russell Road area are likely to be greater than they would with Phase 1b contributing, although still well within EN limits. Clearly, later commissioning of Phase 1b will start generating stray current interference on the Phase 1b Test Sites but we would expect a redistribution of stray current effects in the Russell Road area, to the extent that stray current interference from the Phase 1a route is likely to reduce once Phase 1b is connected in and operating.

Again it is stressed that the control of stray currents has been taken into account in the Phase splitting option assessment. It was a contributory factor in the choice, but in the event did not alter the choice when all criteria had been taken into consideration.

## 11. DEPOT

There are two main potential impacts on the Depot provision: stabling and the Control Room. The impact will depend mainly on the decision on how many trams to cater for.

There are no other implications arising from the optimistic or pessimistic scenarios.

### 11.1 Stabling

Additional points and trackwork can be provided during possessions without adversely affecting the operation of Phase 1a in much the same way that the track could be modified at the Roseburn Junction.

### 11.2 Control Room

Impacts on the Control Room and staffing are dealt with elsewhere.

# 12. OVERHEAD LINE EQUIPMENT

## 12.1 Introduction

The current SDS indicative Overhead Line Equipment design provides for electrifying the inbound, outbound and spur lines into the start of the Roseburn Corridor.

The main Overhead Line Equipment wire tension lengths, at the delta junction, electrify the inbound and outbound lines from Section 2A through to Section 5A. Separate tension lengths are used to electrify the inbound and outbound lines from Section 2A through to Section 3A and this is also the same for the North and South spurs.

For the electrical sectioning of the delta junction, there are three isolator locations with one at each corner of the delta junction. Each location consists of one isolator, two section insulators and feeder connections from the overhead wires to the positive reinforcing cable.

On Russell Road Bridge there are Overhead Line Equipment poles, located on the bridge, that support the overhead wires over the inbound and outbound tracks, and the spurs.

There is no difference between the approach whether the optimistic or pessimistic scenario is chosen.

## 12.2 Design Considerations

If Phase 1b is to be built separately to Phase 1a then this should have little impact on the Overhead Line Equipment configuration in this area as the Overhead Line Equipment electrifying the lines into Section 3A can be omitted without significant alterations to the Overhead Line Equipment electrifying the lines from Section 2A to Section 5A. Some Overhead Line Equipment masts may have to be relocated but this should present few if any problems.

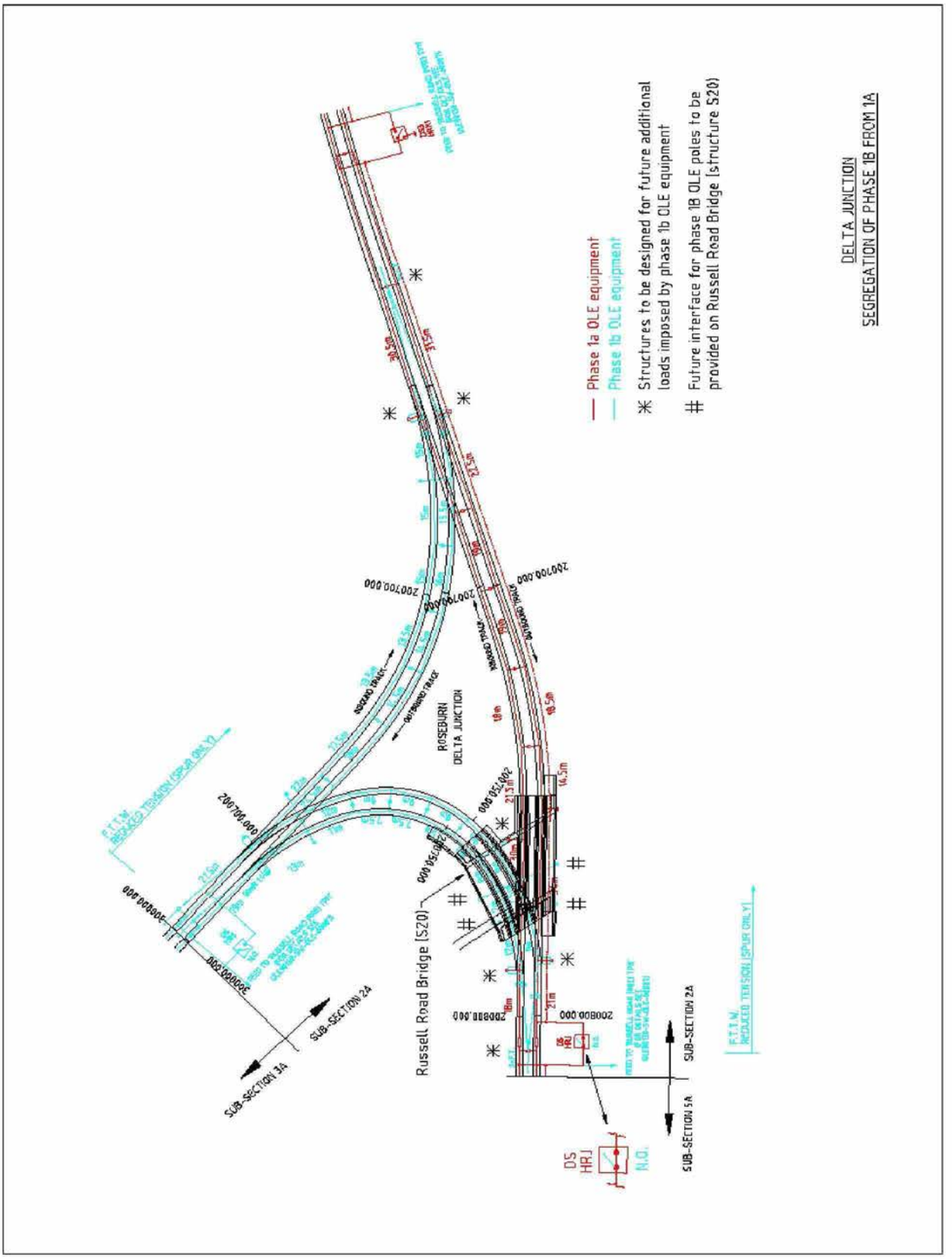
Consideration must, however, be given to the Phase 1a/1b interfaces such as anchor structures (terminating Phase 1b overhead wires but also supporting Phase 1a overhead wires) and twin cantilever structures (supporting both Phase 1a and 1b wires). These structures must still allow for Phase 1b wires for future installation. Also there must be provision for the Overhead Line Equipment poles on Russell Road Bridge.

As advised by the Traction Power discipline, by separating Phases 1a and 1b infrastructure it is possible to delay the implementation of Russell Road Track Paralleling Hut (RRE) and treat it as a phase 1b site. Should **tie** decide to take this option in separating Phases 1a and 1b, a feeding regime needs to be implemented between Tram Jenner's Depository TSS (JDE) and Tram Haymarket Terrace 01 TSS (HTE) that is characteristic of a typical double end fed electrical section.

In this scenario, it is advised that the section insulator points and associated isolators proposed (including feeder poles and feeder connections) at the east and west end of the delta are installed under Phase 1a scope in readiness for RRE and delta implementation/operation at completion of Phase 1b. SDS would advise that the

isolators are configured to run Normally Closed (NC) to facilitate double end feeding between JDE and HTE, (As opposed to one Normally Open (NO) and one Normally Closed (NC) as per requirement at completion of Phase 1b). The isolator at the west end of the delta (DS/HRJ) should be locked in the Normally Closed (NC) position at completion of Phase 1a and treated as non-operational. The isolator at the east end of the delta (DS3/HRX1) should be fully operational to act as a sub-sectioning point for the crossover/turnback facilities to the east in Haymarket Yards. As an additional or alternative measure, full section jumpers could be added to the overhead wires to bypass the section insulators.

When Phase 1b is implemented the said isolators would be normally operational as defined by service positions highlighted in ULE90130-SW-OLE-00007 V6.


DELTA JUNCTION
SEGREGATION OF PHASE 1B FROM 1A
Phase 1a OLE equipment
Phase 1b OLE equipment
Structures to be designed for future additional loads imposed by phase 1b OLE equipment
Future interface for phase 1B OLE poles to be provided on Russell Road Bridge (structure S20)
ROSEBURN DELTA JUNCTION
Russell Road Bridge (S20)
SUB-SECTION 2A
SUB-SECTION 3A
SUB-SECTION 5A
DS HRJ N.O.
F.T.I.W. REDUCED TENSION (SPUR ONLY)

## 13. SUPERVISORY CONTROL AND COMMUNICATIONS

All the Supervisory Control and Communications functionality for Edinburgh Tram makes use of one or more of the following three networks:-

Operational Data Network (ODN) – a high reliability data network using optical fibre running in ducts close to the tram route and multiplexers at each tramstop and substation which communicates with master equipment at the Depot.

Operational Radio System (ORS) – a radio system with basestations at various locations along the route or at high locations away from the route, which together will provide coverage to hand portable radios anywhere on or near the Edinburgh Tram route.

Telephone Network – a network which uses the Operational Data Network as the transmission medium to provide fixed voice communications within the Depot and between the Control Room and tramstop Passenger Help / Passenger Emergency Help Points or substation phones.

Originally the Supervisory Control and Communications systems were planned to cater for the Phase 1a and Phase 1b sections of the route. This section provides an overview as to the necessary Supervisory Control and Communications changes required to the infrastructure to serve the truncated route and the necessary works required when the Phase 1b section of the route is implemented.

There is no difference between the optimistic and pessimistic scenarios.

### 13.1.1 Definitions and Acronyms

| Acronym | Definition |
|---|---|
| CCTV | Closed Circuit Television |
| ETN | Edinburgh Tram Network |
| ODN | Operational Data Network |
| ORS | Operational Radio System |
| PABX | Private Automatic Branch Exchange |
| PH/PEHP | Passenger Help / Passenger Emergency Help Point |
| PID | Passenger Information Displays |
| PSTN | Public Switched Telephone Network |
| SCADA | Supervisory Control And Data Acquisition |
| SCC | Supervisory Control & Communications |
| TPDS | Tram Protection and Detection System |

### 13.2 Operational Data Network

### 13.2.1 Current Proposal Phases 1a and 1b

The current proposal is that the Operational Data Network will consist of three 'flattened' optical fibre rings with multiplexers at each substation. The topology of a ring creates a diverse route for the data, so that operational traffic can be re-routed in the opposite direction in the event of a single break within the ring, thereby providing the necessary network resilience. The three rings connect the substations within three geographically

separate sections of the route. Each ring extends to the depot where the master equipment is located.

| | |
|---|---|
| Ring 1 | connects the depot with the substations along the section of the route from Edinburgh Airport to Russell Road Track Paralleling Hut. |
| Ring 2 | connects the depot with the substations along the section of route known as the Roseburn Corridor to Granton Square which includes Tram Granton View Substation. This ring is not required should Phase 1b operation not be required. |
| Ring 3 | connects the depot with the substations along the section of route from Tram Haymarket Terrace 1 to Tram North Leith Sands substations |

All rings are independent of one another, running on separate fibres within the same cable. The traffic from the three rings is only combined at multiplexing equipment within the Depot equipment room for onward transmission to the duplicated Control Room Wide Area Network.

Tramstops are connected in a chain using fibres independent of the substation ring. At each end of a chain of Tramstops the chain is connected to a communications multiplexer within the substation and the traffic generated by Tramstops is added to the main ring. The maximum number of Tramstops between any two substations is five. By terminating each tramstop at two substations provides the required resilience to a single failure.

The following diagram illustrates the current proposal.

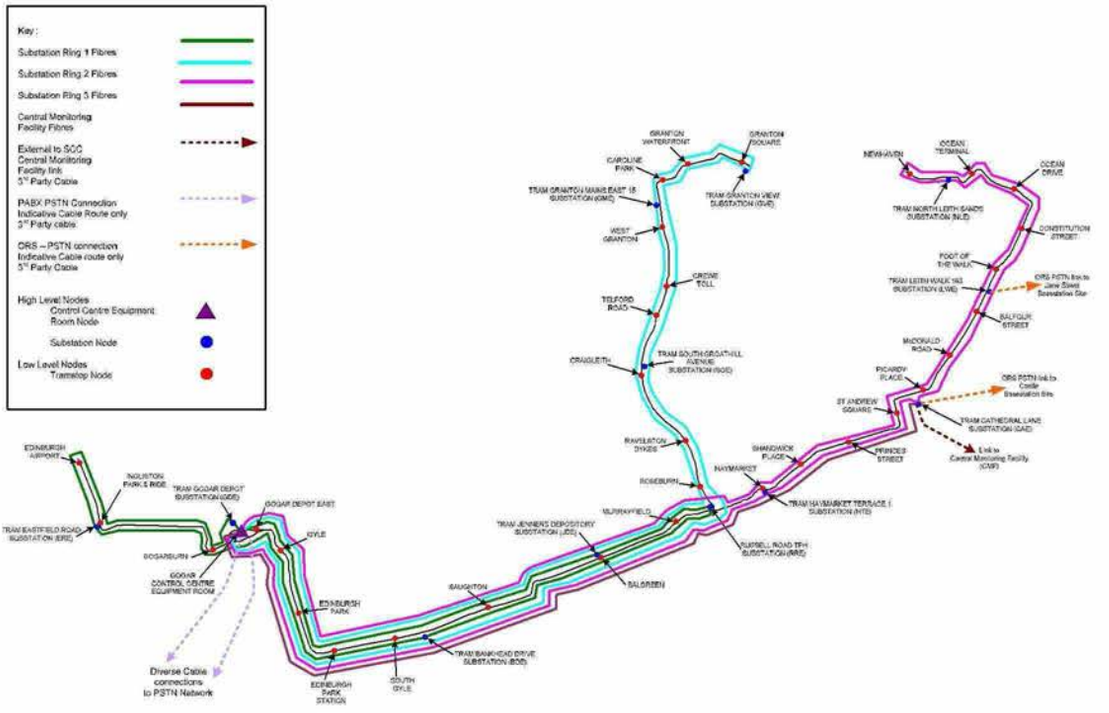



Figure 1 - Operational Data Network - Current proposal Phase 1a and 1b

13.2.2 Proposal for Phase 1a only

The proposal is that Ring 2, which serves the Roseburn Corridor to Granton Square section, is only partially installed. Between the Depot and the Roseburn Junction Ring 2 fibres will be installed during the main construction phase. One end of these Ring 2 fibres will be terminated on an optical distribution frame within the Depot equipment room, with the remote end terminated on an optical distribution frame in a cabinet close to the Roseburn Junction. All draw pits and junctions in the duct work necessary to accommodate the diverging duct route to the Roseburn Corridor are to be installed at the time of Phase 1a construction and at a sufficient distance from the main route so that the future enabling works do not disrupt traffic on the Haymarket – Murrayfield route. End to end testing should be carried out to ensure fibre integrity and the fibres marked 'For future use' and capped out of use.

Fibres for rings 1 and 3 will be installed in their entirety and are not influenced by this proposal.

Within the Depot equipment room, rack space, electrical supplies, cable routes, interfaces, terminations, optical distribution frames etc. will be allocated for the necessary Ring 2 multiplexing equipment. The reserved power, space and cabling requirements of the Ring 2 multiplexer will be very similar to those required for the installation of the Ring 1 and Ring 3 multiplexers. All breakers, terminations and rack space etc., are to be marked and reserved 'For future use' and capped out of use.

Overall equipment room facilities, such as Uninterruptible Power Supplies, breaker panels, air conditioning capacity etc. are to remain unchanged from that required for a 3-ring implementation.

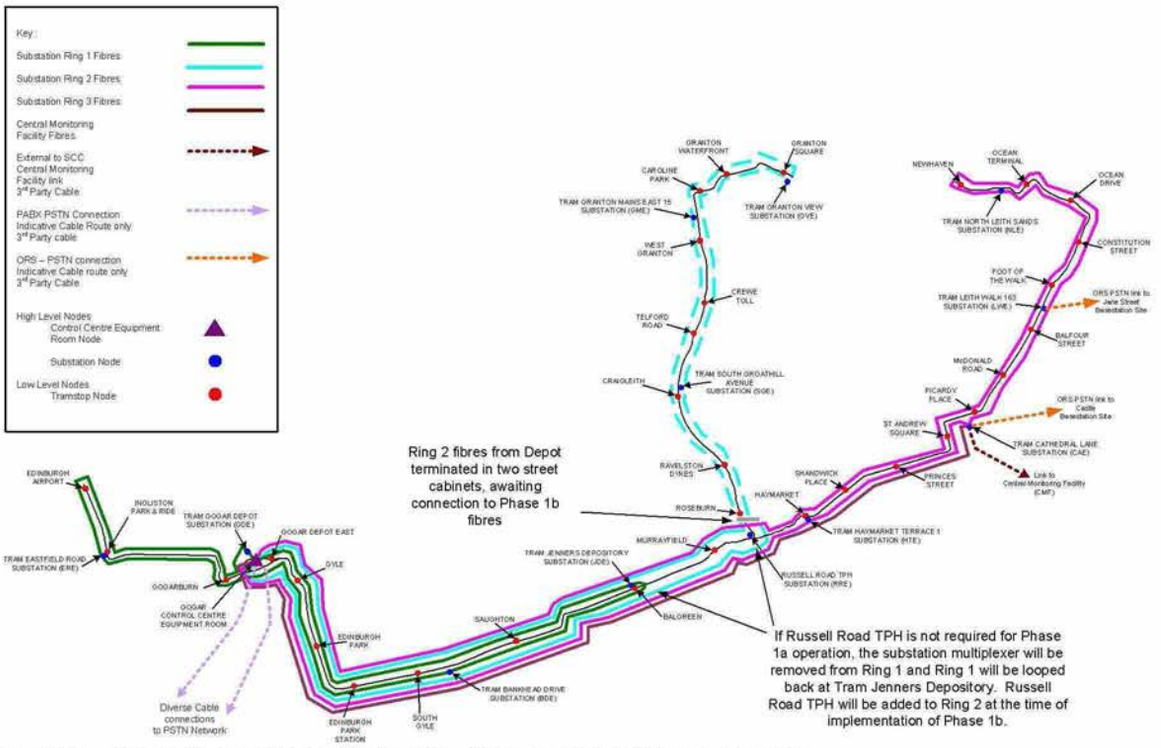



Figure 2 - Operational Data Network - Proposal for Phase 1a only

### 13.2.3 Bringing Phase 1b into service

At the time that Phase 1b is installed, it will be necessary to install the Operational Data Network Ring 2 multiplexer within the Depot equipment room and make the necessary fibre connections to the optical distribution frame, power etc. The new multiplexer and the Equipment Room/Control room Wide Area Network will require to be configured to work together. This work can be carried out during successive periods of 'Engineering hours' with little risk and prior to the main possession required at Roseburn Junction.

The fibre that is to run along the Phase 1a route will connect to the existing Ring 2 fibres at the optical distribution frame installed within the street cabinet at Roseburn Junction at the time of Phase 1a construction. This can be done without affecting revenue service.

## 13.3 Telephone Network

### 13.3.1 Current Proposal Phases 1a and 1b

The current SDS proposal is that there are two PABXs, the Service PABX and the Emergency PABX, both of which are located with the Depot equipment room. The Service PABX not only handles incoming and outgoing calls to Control room to and from the PSTN, but also Passenger Help/Passenger Emergency Help Points, calls between

extensions within the Depot and to extensions at the substations. The Emergency PABX is provided to maintain the high levels of availability and diversity necessary to communicate with the emergency services under conditions of failure of the Service PABX.

Connections between the Service PABX and the remote extensions (substation phones and Passenger Help / Passenger Emergency Help Points on the Tramstops) are via trunk interface cards fitted to the Operational Data Network substation and tramstop multiplexers.

To accommodate the requirements of Phase 1a and 1b it has been calculated that the PABX will require a minimum of 208 extensions.

13.3.2 Proposal for Phase 1a only

Phase 1b currently requires 21 extensions, i.e., an approximate reduction of only 10%. The Service PABX should be sized from the onset to cater for the minimum of 208 extensions. The installation of a fully dimension PABX from the onset will have minimal cost impact.

The emergency PABX remains unaffected.

13.3.3 Bringing Phase 1b into service

As Phase 1b is installed, it will only be necessary to configure the ports on the service PABX and connect the PABX by the necessary trunk cards to the Operational Data Network ring 2 multiplexer at the Depot and carry out corresponding connections at the remote end. This should not have any impact on an operational tram service and can be carried out during 'Engineering hours'.

## 13.4 Operational Radio System

13.4.1 Current Proposal Phases 1a and 1b

The current proposal for the Operational Radio System is that there are 4 radio basestation sites located at:-

- Depot;
- Bankhead Drive;
- Edinburgh Castle; &
- Jane Street.

To cater for the anticipated traffic each site will be equipped with one control channel and three traffic channels. The proposed siting of the basestations has been determined using radio propagation modelling software so that there is coverage to the whole of Phases 1a and 1b, sufficient to provide communications to hand portable mobiles on or near the route. The following figure, extracted from the Propagation Modelling Report,



**Legend**

| Colour | Best Serving Basestation |
|---|---|
| | Outside planned coverage |

illustrates the 'Best Serving' basestation showing the coverage to Trams provided by each basestation. It should be noted that coverage to Phase 1b is provided by Edinburgh Castle (shown in blue). It should also be noted that the coverage provided by Edinburgh Castle also serves part of Phase 1a route.

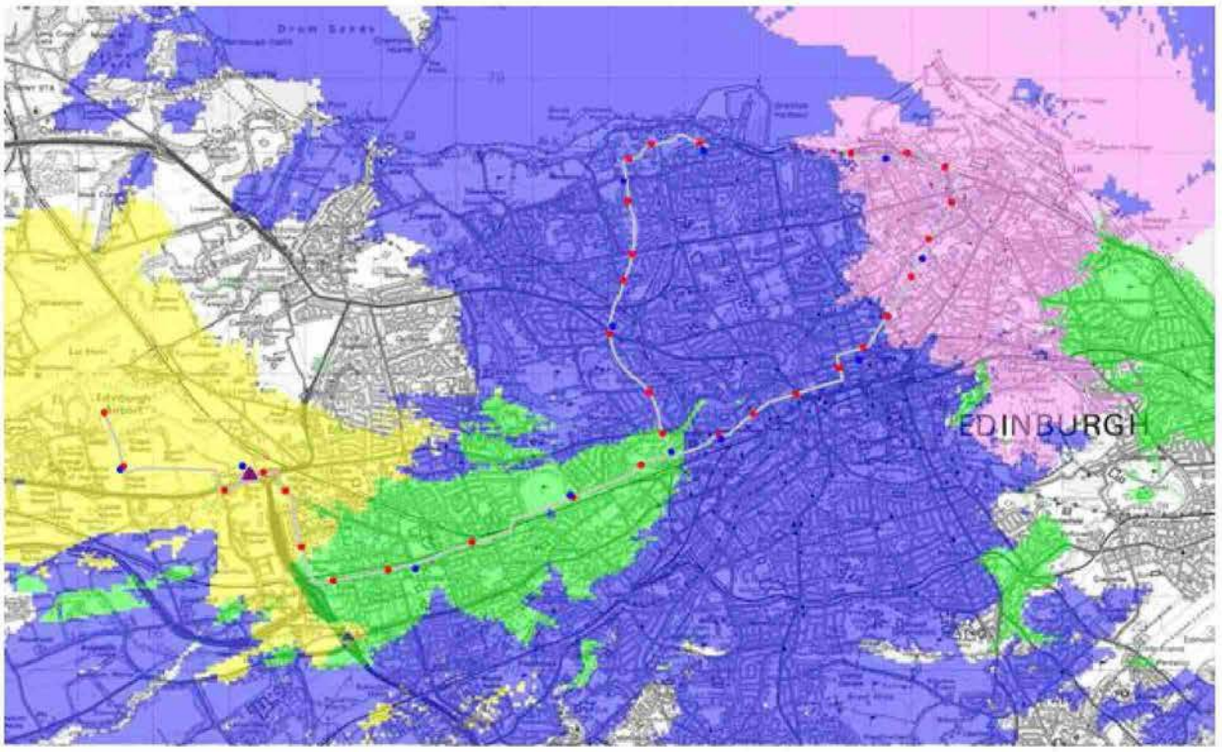



Figure 3 - Trams, best serving basestation

13.4.2 Proposal for Phase 1a only

As Edinburgh Castle provides coverage to Phase 1a and 1b sections of the route, the basestation is necessary during Phase 1a only operation. Due to planning constraints the antenna is co-linear (omni-directional) so there is no scope to realign the antenna orientation to optimise for Phase 1a areas only.

Due to the lower number of trams operating during the Phase 1a operational phase it might be thought that there might be some scope to reduce the number of traffic channels at the Castle basestation as the number of mobiles served by the basestation is reduced (this assumes an even distribution of trams along the route to make and receive calls). However, recalculating the call statistics for the reduced number trams which will operate the service shows that it will not be possible to reduce the number of traffic channels at any of the basestations.

Hence no changes are proposed to the Operational Radio System.

13.4.3 Bringing Phase 1b into service

As no changes are proposed to the fixed infrastructure, the only additional works required is to commission the tram mobile radios and associated hand portable radios and add them to the equipment database with the Operational Radio Network management facility. This can easily be carried out during operational hours at no risk to revenue service.

## 13.5 Other Supervisory Control and Communications Systems

### 13.5.1 Closed Circuit Television

Closed Circuit Television The Closed Circuit Television (CCTV) system makes use of the Operational Data Network to transmit images from the Tramstops and substations to the Control Room where they are displayed on a video wall or on workstation monitors. The late implementation of Phase 1b will reduce the number of cameras by approximately 25% when compared to the number required for Phase 1a and 1b. It is therefore recommended that sufficient capacity is built into the control and display equipment from the onset.

### 13.5.2 Passenger Help/Passenger Emergency Help Points

The Passenger Help/Passenger Emergency Help Points are a specialised telephone which operates over the Telephone Network. As discussed in Section 13.2, the Service PABX should be installed with provision for the whole scheme from the onset.

### 13.5.3 Passenger Information Displays

The Passenger Information Displays (PIDs) are mounted at each tramstop and receive their data from a Passenger Information Display controller in the Depot equipment room over the Operational Data Network. The PID controller should be installed with provision for the whole scheme from the onset.

### 13.5.4 Supervisory Control And Data Acquisition

The Supervisory Control And Data Acquisition (SCADA) is required primarily at substations. The data transmission from the outstation to the central SCADA server within the Depot equipment room is via the Operational Data Network. The SCADA server should be installed with provision for the whole scheme from the onset.

### 13.5.5 Tram Position and Detection System

The Tram Position and Detection System equipment is centralised about each tramstop. The data transmission from the TPDS controller to the central TPDS server within the Depot equipment room is via the Operational Data Network. The TPDS server should be installed with provision for the whole scheme from the onset.

### 13.5.6 Traction Power Mass Trip/Intertrip Cabling

The Traction Power Mass Trip / Intertrip Cabling is to built to accommodate the Phase 1b section, but where circuits are to 'T' off to the future Phase 1b, section these should be replaced by hard wired links within the mass trip panel within the substation.

13.5.7 Control Room

No changes are anticipated to the Control Room layout as proposed for Phase 1a and 1b operation as any future works to accommodate new equipment will be disruptive to the operating environment.

13.5.8 Equipment Room

It has been recommended that most systems should be installed with the provision for the whole scheme from the onset. Where equipment is not installed within the equipment room during the construction of Phase 1a, provision must be made for its space, power, cabling, cooling requirements, etc., from the onset.

## 13.6 Conclusions

The major Supervisory Control and Communications network effected should Phase 1b not be built at the same time as Phase 1a is that of the Operational Data Network. However provision should be made at the time of construction to add the necessary equipment without undue impact on the revenue tram service. The main provisions to be made during the construction of Phase 1a for 1b are:-

Sufficient space, power, cabling, interface ports, air conditioning etc. within the depot equipment room;

The laying of fibre optic cables from the Depot equipment room to the vicinity of Roseburn Junction;

At Roseburn Junction laying the duct 'T' pieces necessary for the Phase 1b route and for a sufficient distance so working on these ducts does not effect revenue traffic on the Phase 1a part of the route;

Terminating the fibre optic cable necessary for Phase 1a in a roadside cabinet near Roseburn Junction.

All other networks (Operational Radio System and Telephone Network) are to remain basically unchanged.

Only small savings to be made by not installing the SCC equipment necessary for Phase 1b should that section of the route not be built from the onset and that the Supervisory Control and Communications elements of Phase 1b implementation can be brought into service with the minimum of disruption to revenue traffic.

Consideration should be given to equipment obsolescence. This is the main issue between the optimistic and pessimistic scenarios.

## 13.7 Optimistic

In the optimistic scenario, all of the Supervisory Control and Communications equipment should be purchased as part of the Phase 1a works to avoid early obsolescence preventing the extension of the purchased system for Phase 1b.

Careful attention to future proofing of the equipment could avoid this being necessary and this is a matter for the InfraCo.

A potential risk is that critical items of equipment for Phase 1b are under-provided either because of pilfering or damage or an under-estimate of what was needed.

## 13.8 Pessimistic

In the pessimistic scenario, no unnecessary equipment should be purchased for Phase 1b as it is possible that the entire equipment may be replaced and would be done as part of the development of Phase 1b.

Careful attention to future proofing of the equipment would avoid any abortive costs and this is a matter for the InfraCo.

## 14. INTEGRATED FARE COLLECTION

The ticket machines and associated equipment of the Integrated fare Collection system supplied with Phase 1a will be integrated into the infrastructure systems of the Edinburgh Tram Network.

Any interface equipment for the Supervisory Control and Communications system should be considered against the optimistic and pessimistic scenarios and this is dealt with in that section of this report.

Subject to this, there should be no need to purchase the equipment for the Integrated Fare Collection system until it is needed and therefore there are no material differences between the optimistic and pessimistic scenarios.

## 15. LOW VOLTAGE SUPPLIES

It is envisaged that the Distribution Network Operator provides the low voltage supply connection to each facility. This means that the equipment that will not be needed at Roseburn Junction for Phase 1a but will be needed for Phase 1b can have a supply provided at the time when Phase 1b is being constructed and the new equipment requires a power supply.

Away from the Roseburn Junction, the low voltage supply will be included as part of the works in the same manner.

There is therefore no issue for the Low Voltage Supply and therefore there is no difference between the optimistic and pessimistic scenarios.

## 16. STREET LIGHTING

Street lighting is provided to illuminate the Roseburn walkway / cycleway. The issue is discussed in the ROADS section

## 17. DRAINAGE

Near the Roseburn Junction the Phase 1b corridor drains south towards Phase 1a works. The outfall is into an existing access chamber in Balbirnie Place via a new access chamber (2A/N03/15).

It is therefore proposed that the access chambers in the vicinity of the Roseburn Junction are constructed as part of Phase 1a and that stubs are provided to facilitate the later connection to the Phase 1b.

This means that chamber 2A/N03/15 will be constructed as designed. Chamber 2A/N03/13 will be constructed to carry the flow from Phase 1a works (from chamber 2A/N03/12) and be provided with a stub to allow future connection to chamber 2A/N03/07. Chamber 2A/N03/09 should be constructed with a stub to facilitate connection to the future chamber 2A/N03/08.

This would take all drainage diversions to an economical but practical point, such that a clear and clean connection is derived for the future Phase 1b work.

There is no difference between the optimistic and pessimistic scenarios although chamber 2A/N03/09 and its connection to 2A/N03/10 could be omitted if the western chord of the Roseburn Junction is deemed unlikely.

Drawing No. ULE90130-02-DNE-00003 of the proposed drainage plan is attached.

## 18. CABLE DUCTING

The separation of Phases 1a and 1b works where the construction of Phase 1b is to be delayed, will have little effect on the ducting requirements along Section 3 and possibly only minor effects on the rest of the System. The current ducting design at the Roseburn Junction Delta is the main interface and should be installed in its entirety under Phase 1a works and include a nominal length of the current design into Sub Section 3A. This will allow for the completion of all works under Phase 1a whilst minimising disruption to the operational tramway when work recommences under Phase 1b. Draw pits should be installed where the ducting temporarily terminates just inside Sub Section 3A, on both sides of the track, for ease of continuity when Phase 1b commences.

Subject to the discussion below, there are no other differences between the optimistic and pessimistic scenarios.

### 18.1 Track Auxiliaries

All ducting requirements for the Track Auxiliaries equipment under Phase 1a including in and around the Roseburn Junction Delta will be installed as currently designed and as referenced above.

### 18.2 Traction Power Supply

Should Option 1 be chosen (i.e., retain GVE in Sub Section 3C) then the ducting design across the gap (previously Section 4) will be maintained to connect GVE to the System. Additional reinforcement cable may also be required in certain areas as referenced under Option 3; this will be considered subject to more detailed investigative work on the Traction Power Supply performance should the decision be made to separate the two phases.

Should Option 2 be chosen (i.e., add a new sub station at Leith Docks – LDE), then there will be no change to the Ducting Design.

Should Option 3 be chosen (i.e., additional reinforcement cable), then the Ducting Design will be reviewed for revision accordingly in all areas referenced.

Should Option 4 be chosen (i.e., the potential for relaxation of full passenger service with any one sub station out of service) then there will be no change to the Ducting Design if the relaxation is acceptable.

Whichever option is chosen the Traction Power Supply ducting requirements throughout the rest of Phase 1a including in and around the Roseburn Junction Delta will be installed as currently designed and as referenced above.

### 18.3 Supervisory, Control and Communications (SCC) Systems

There will be no revision to the Ducting Design for the Supervisory Control and Communications Systems other than the inclusion of minor ducts from termination cabinets located where the ducting terminates just inside Sub Section 3A.

## 18.4 Low Voltage Supplies (LVS)

All ducting requirements for the Low Voltage Supplies under Phase 1a including in and around the Roseburn Junction Delta will be installed as currently designed and as referenced above.

## 19. UTILITIES

The design to move utilities out of the Edinburgh Tram Network space for the Roseburn Junction where Phase 1a and 1b meet is complete. There will need to be a small re-design exercise to the relevant utilities to take all utility diversions to an economical but practical point (valve, chamber or draw pit) at the junction, such that a clear and clean connection is derived for the future Phase 1b work.

There is no clear distinction between optimistic and pessimistic scenarios, this being subject to an ad hoc approach to each service.

Consideration to the utilities programming would be necessary in the event of separation of Phase 1a from Phase 1b. At present there is a MUDFA programme of utility diversion work starting some nine months ahead of the main Edinburgh Tram Network Infrastructure work. It would be necessary to review the same philosophy of diversions for a separate Phase 1b contract of work recognising the economies of time and scale due to the restricted access for construction works within the Roseburn Corridor. Due to the construction access arrangements and large amounts of earthwork reconfiguration involved, it may be seen as reasonable to carry out the utility diversions within the framework of a total InfraCo contracted scope of work.

## 20. GEOTECHNICAL

The geotechnical implications are directly associated with the strategic choice of diverting the existing footway / cycleway.

This is explained in the Roads section of this report.

### 20.1 Optimistic

These earthworks would include the regrading of the existing embankment on the Roseburn Corridor and would effectively be advance works for Phase 1b. The earthworks would require the excavation of the existing embankment over a distance of approximately 100m to the north of the Phase 1a works along the corridor towards the Roseburn Terrace underline bridge to a point where the earthworks levels tie in with those required for the Phase 1b works. As part of these works, a ramped cycleway would be constructed on the re-graded earthworks slope to allow access to both Russell Road and Balbirnie Place.

### 20.2 Pessimistic

The earthworks associated with this option are the minimum required for the construction of Phase 1a and would comprise the excavation of a 1:2 slope cut into the existing embankment on the Roseburn Corridor. The cutting would be located the minimum distance back from the working area required for the construction of the Phase 1a works. The existing access to both Russell Road and Balbirnie Place would be maintained by the construction of folded ramps within the existing embankment.

## 21. LANDSCAPE

Landscaping will be affected by whether the optimistic or pessimistic choice is made. However, in both cases, the impact is minor.

### 21.1 Optimistic

In the optimistic scenario, the earthworks and roads between the Roseburn Junction and Roseburn Terrace underline bridge will have been constructed. This means that the landscaping will need to be undertaken in order to comply with the Landscape and Habitat Management Plan and other undertakings.

In addition, the temporary landscaping of the formation should be undertaken as an extension to this plan. This would not be costly and could be limited to facilitating the natural re-growth of existing vegetation.

Some additional cost will be incurred because later construction works will inevitably disturb some of the permanent landscaping but this should be limited to ground cover which will repair itself with time.

### 21.2 Pessimistic

The temporary landscaping of the new embankment supporting Phase 1a works at the Roseburn Junction would be required. This could be an extension of the approach made in the Landscape and Habitat Management Plan. The embankment would be buried by the later earthworks to support Phase 1b works.

Drawing No. ULE90130-02-PLG-00023 shows the landscaping to be undertaken with the construction of Phase 1a.

## 22. IMPLICATIONS AND RESTRICTIONS TO CONSTRUCTION ACCESS TO PHASE 1B SITE

The implications for construction access to the Phase 1b construction site vary between the optimistic and pessimistic scenarios.

The Russell Road construction access is close to the Roseburn Junction and the use of this access point would be affected by the works needed to implement the optimistic option.

The Roseburn Terrace underline bridge will act as a break in the continuity of the construction site until it has been constructed. This will have a considerable impact on construction logistics for the construction of Phase 1b whether it is built with Phase 1a or not.

### 22.1 Optimistic

In the optimistic scenario, the footway / cycleway, earthworks, drainage and street lighting for the section between the Roseburn Junction and the Roseburn Terrace underline bridge would be provided as part of the Phase 1a works as described elsewhere in this report.

This means that a large amount of the necessary works in this area will have been completed, but the use of the Russell Road construction access point will be limited by the existence of some of the final works. In particular, the footway / walkway could carry some construction traffic (it will be closed for public use during the construction of Phase 1b) but would be unsuitable (as designed) for heavy plant access for the construction of Roseburn Terrace underline bridge.

However, the earthworks to prepare the formation of the tramway will have been undertaken. This would provide a very good route from Balbirnie Place. Balbirnie Place is residential and so unsuitable for general construction traffic but the exceptional movement of specific items of heavy plant should be acceptable. This is likely to include a pile boring rig and possibly a crane.

### 22.2 Pessimistic

There should be no material implications regarding construction access to the Phase 1b site. The temporary footway / cycleway link would need to be removed but the entire site will be closed during construction in any case.

The nearest relevant access point is Russell Road. This would not be affected by the Phase 1a works.

## 23. BUDGET AND COMMERCIAL

The estimated cost implications are attached.

They assume the base costs are accepted for each of Phases 1a and 1b.

Because the report assumes Phase 1b will be built later, it will be built under a new procurement process. This will attract a considerable increase in the cost of Phase 1b compared with the current estimates and offers.

A budget multiplier of 40% has been assumed.

The cost implications are changes to the base cost assumptions.

This means that Phase 1a base costs and changes to Phase 1a costs are based on the current prices under consideration.

However, all Phase 1b base costs and changes to them are subject to the estimated 40% escalation.

### 23.1 Conclusion

We estimate that adopting the Optimistic scenario will **save** circa £3.5 million on the combined base costs of building both Phases and that adopting the Pessimistic scenario will **add** circa £2.5 million to the combined base costs.

**BASE COST VARIATIONS FOR BUILDING PHASE 1a and 1b SEPARATELY**

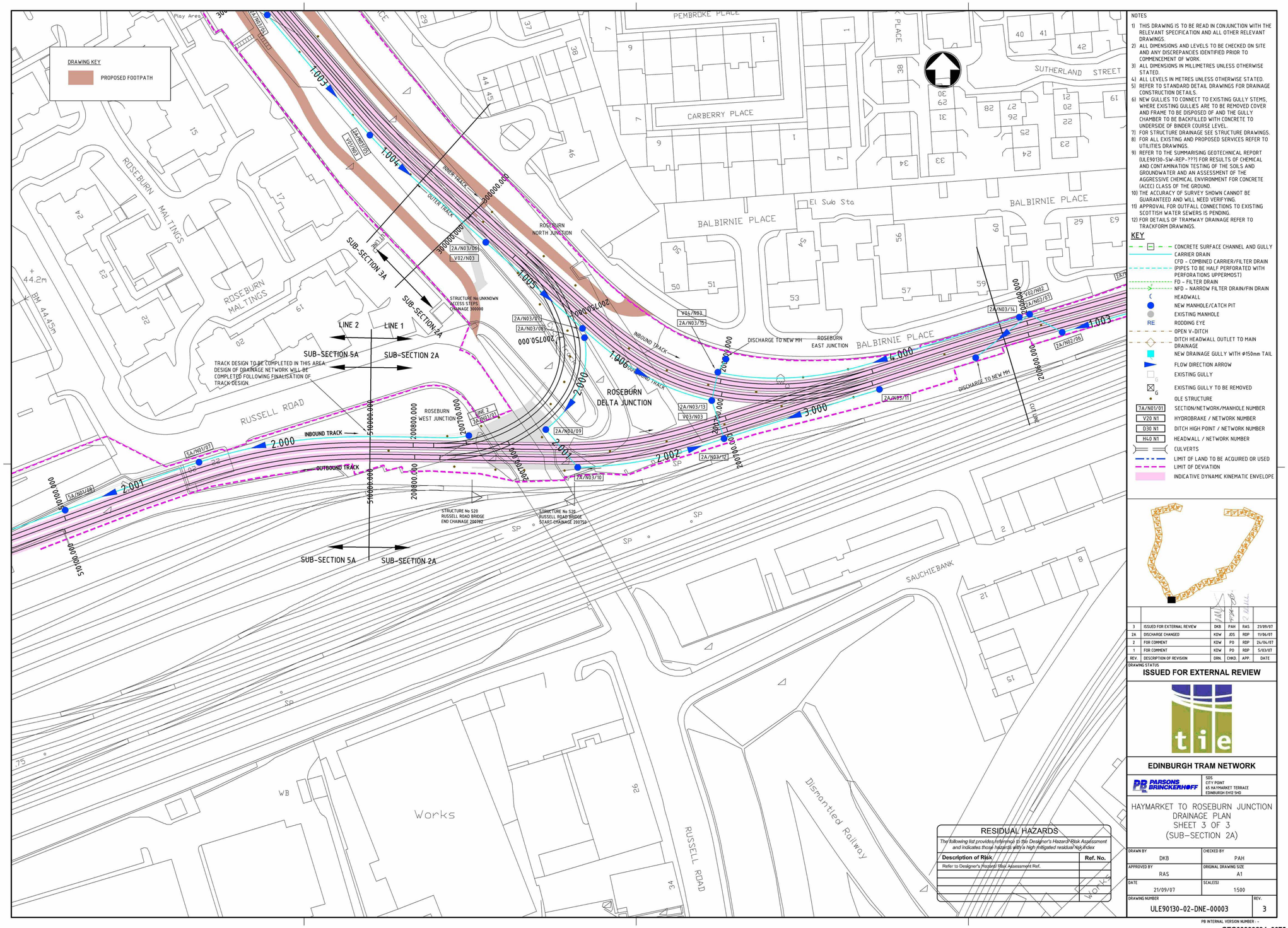
| Scenarios | OPTIMISTIC | | PESSIMISTIC | | NOTES |
|---|---|---|---|---|---|
| Cost breakdown | Phase 1a £k | Phase 1b £k | Phase 1a £k | Phase 1b £k | |
| **3 DESIGN** | | | | | |
| Temporary works design | 50 | 0 | 110 | 0 | Includes temporary cut-off and connection design plus abortive works design. |
| **5 TRAMS** | | | | | |
| Premium for 4 extra trams | 8,000 | -8,000 | 0 | 0 | Total Estimated Tender price |
| **6 TRACK ALIGNMENT** | | | | | |
| Main line track | -250 | 250 | -200 | 200 | Deletion of Roseburn Junction Switches (2) and crossing |
| Extra Depot sidings | 200 | -200 | 0 | 0 | Includes switches (2) |
| **7 TRACK AUXILIARIES** | | | | | |
| Point m/cs,Signals, P.Inds, Signs, etc. | 0 | 0 | 0 | 0 | |
| **8 ROADS** | | | | | |
| Construct foot/cycle path at Roseburn | 30 | -30 | 15 | 0 | Temporary diversion in Pessimistic Scenario |
| **9 STRUCTURES** | | | | | |
| Russell Rd bridge | 0 | 0 | 0 | 0 | Bridge design unaffected |
| **10 TRACTION POWER SUPPLIES** | | | | | |
| Option 1 (Build GVE) | 650 | -650 | | | Excludes cable bridge |
| Option 2 (Additional Leith Substation) | | | 650 | -450 | Includes relocating the package substation to GVE |
| **11 DEPOT** | | | | | |
| Adjustment to Depot construction | 0 | 0 | 0 | 0 | Track and Control Room dealt with elsewhere |
| **12 OVERHEAD LINE EQUIPMENT** | | | | | |
| | 0 | 0 | 0 | 0 | |
| **13 SUPERVISORY CONTROL AND COMMUNICATIONS** | | | | | |
| 1b hardware in storage | 100 | -100 | 0 | 0 | (Ducting inc., in Item 10) |
| Replace all hardware / software | 0 | 0 | 0 | 1,500 | Asumes significant obsolesence |

| | | | | | |
|---|---|---|---|---|---|
| **14 INTEGRATED FARE COLLECTION** | | | | | |
| | 0 | 0 | 0 | 0 | 20% of Phase 1a equpt. |
| **15 LOW VOLTAGE SUPPLIES** | | | | | |
| Unaffected | 0 | 0 | 0 | 0 | No difference |
| **16 STREET LIGHTING** | | | | | |
| Covered under ROADS | 20 | -20 | 10 | 0 | Covered under ROADS |
| **17 DRAINAGE** | | | | | |
| Unaffected | 0 | 0 | 0 | 0 | No difference |
| **18 CABLE DUCTING** | | | | | |
| Unaffected | 200 | -200 | 0 | 200 | |
| **19 UTILITIES** | | | | | |
| Unaffected | 0 | 0 | 0 | 0 | No difference |
| **20 GEOTECHNICAL** | | | | | |
| | 40 | -40 | 10 | 0 | Covered under ROADS |
| **21 LANDSCAPING** | | | | | |
| Temporary landscaping | 10 | -8 | 5 | 0 | Making ground cover good<br>Remove temp landscaping |
| **22 CONSTRUCTION ACCESS** | | | | | |
| | 0 | 0 | 0 | 0 | No significant cost variation |
| **Totals £k** | 9,000 | -8,998 | 490 | 1,450 | |
| **1b Contract Mark Up** | 9,000 | -12,597 | 490 | 2,030 | Assumes 40% uplift to cover New Contract, Small Order, Inflation, Inefficient Working, New Mobilisation and Additional Commissioning |
| **Scenario Totals** | | -3,597 | | 2,520 | |

## 24. OPERATIONAL CONSIDERATIONS

There are no immediate design issues arising from operational considerations other than those dealt with elsewhere in this report. They mainly revolve round the Power Supply System issues.

The interruption to the operation of Phase 1a is limited to a 52 hour (weekend) possession to make the connections for Phase 1b and this seems realistic.




NOTES

1) THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE RELEVANT SPECIFICATION AND ALL OTHER RELEVANT DRAWINGS.
2) ALL DIMENSIONS AND LEVELS TO BE CHECKED ON SITE AND ANY DISCREPANCIES IDENTIFIED PRIOR TO COMMENCEMENT OF WORK.
3) ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.
4) ALL LEVELS IN METRES UNLESS OTHERWISE STATED.
5) REFER TO STANDARD DETAIL DRAWINGS FOR DRAINAGE CONSTRUCTION DETAILS.
6) NEW GULLIES TO CONNECT TO EXISTING GULLY STEMS, WHERE EXISTING GULLIES ARE TO BE REMOVED COVER AND FRAME TO BE DISPOSED OF AND THE GULLY CHAMBER TO BE BACKFILLED WITH CONCRETE TO UNDERSIDE OF BINDER COURSE LEVEL.
7) FOR STRUCTURE DRAINAGE SEE STRUCTURE DRAWINGS.
8) FOR ALL EXISTING AND PROPOSED SERVICES REFER TO UTILITIES DRAWINGS.
9) REFER TO THE SUMMARISING GEOTECHNICAL REPORT (ULE90130-SW-REP-???) FOR RESULTS OF CHEMICAL AND CONTAMINATION TESTING OF THE SOILS AND GROUNDWATER AND AN ASSESSMENT OF THE AGGRESSIVE CHEMICAL ENVIRONMENT FOR CONCRETE (ACEC) CLASS OF THE GROUND.
10) THE ACCURACY OF SURVEY SHOWN CANNOT BE GUARANTEED AND WILL NEED VERIFYING.
11) APPROVAL FOR OUTFALL CONNECTIONS TO EXISTING SCOTTISH WATER SEWERS IS PENDING.
12) FOR DETAILS OF TRAMWAY DRAINAGE REFER TO TRACKFORM DRAWINGS.

KEY

- CONCRETE SURFACE CHANNEL AND GULLY
- CARRIER DRAIN
- CFD - COMBINED CARRIER/FILTER DRAIN (PIPES TO BE HALF PERFORATED WITH PERFORATIONS UPPERMOST)
- FD - FILTER DRAIN
- NFD - NARROW FILTER DRAIN/FIN DRAIN
- HEADWALL
- NEW MANHOLE/CATCH PIT
- EXISTING MANHOLE
- RE RODDING EYE
- OPEN V-DITCH
- DITCH HEADWALL OUTLET TO MAIN DRAINAGE
- NEW DRAINAGE GULLY WITH ø150mm TAIL
- FLOW DIRECTION ARROW
- EXISTING GULLY
- EXISTING GULLY TO BE REMOVED
- OLE STRUCTURE
- 7A/N01/01 SECTION/NETWORK/MANHOLE NUMBER
- V20 N1 HYDROBRAKE / NETWORK NUMBER
- D30 N1 DITCH HIGH POINT / NETWORK NUMBER
- H40 N1 HEADWALL / NETWORK NUMBER
- CULVERTS
- LIMIT OF LAND TO BE ACQUIRED OR USED
- LIMIT OF DEVIATION
- INDICATIVE DYNAMIC KINEMATIC ENVELOPE

| | | | | | |
|---|---|---|---|---|---|
| 3 | ISSUED FOR EXTERNAL REVIEW | DKB | PAH | RAS | 21/09/07 |
| 2A | DISCHARGE CHANGED | KDW | JDS | RDP | 11/06/07 |
| 2 | FOR COMMENT | KDW | PD | RDP | 24/04/07 |
| 1 | FOR COMMENT | KDW | PD | RDP | 5/03/07 |
| REV. | DESCRIPTION OF REVISION | DRN. | CHKD. | APP. | DATE |

DRAWING STATUS

**ISSUED FOR EXTERNAL REVIEW**

**EDINBURGH TRAM NETWORK**

PB PARSONS BRINCKERHOFF
SDS
CITY POINT
65 HAYMARKET TERRACE
EDINBURGH EH12 5HD

# HAYMARKET TO ROSEBURN JUNCTION DRAINAGE PLAN SHEET 3 OF 3 (SUB–SECTION 2A)

| | |
|---|---|
| DRAWN BY: DKB | CHECKED BY: PAH |
| APPROVED BY: RAS | ORIGINAL DRAWING SIZE: A1 |
| DATE: 21/09/07 | SCALE(S): 1:500 |
| DRAWING NUMBER: ULE90130-02-DNE-00003 | REV.: 3 |

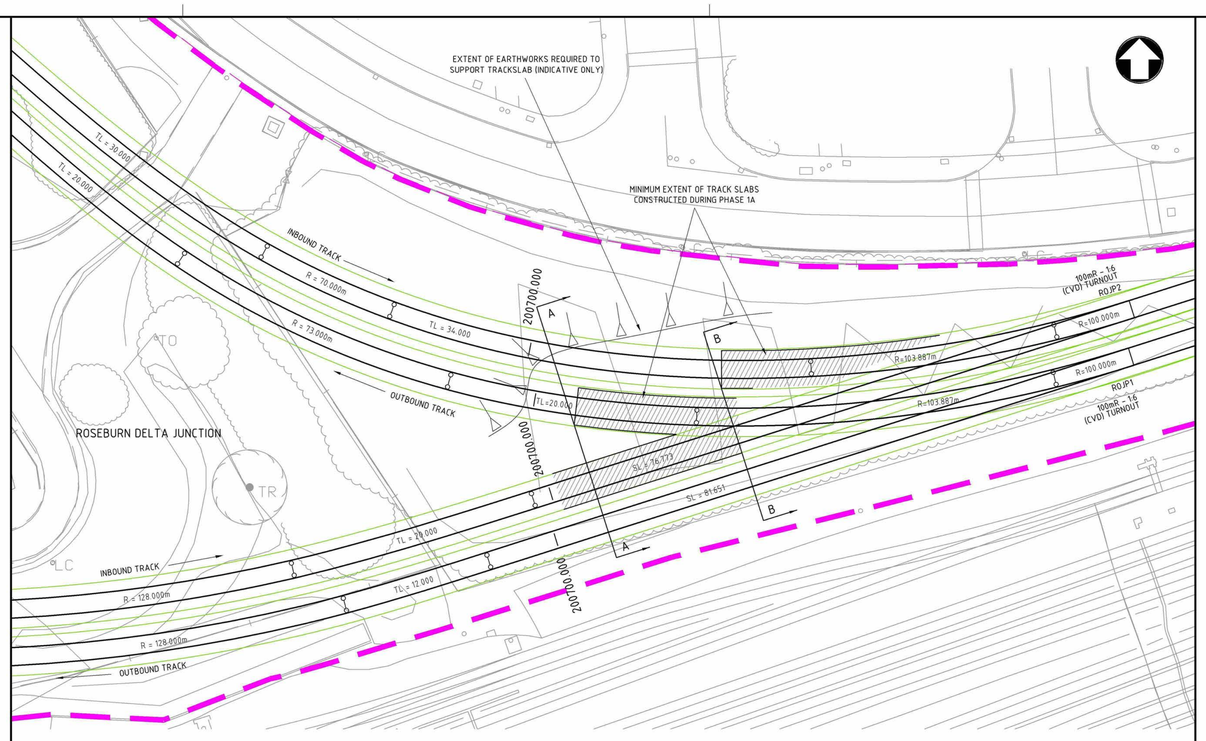
RESIDUAL HAZARDS

*The following list provides reference to the Designer's Hazard Risk Assessment and indicates those hazards with a high mitigated residual risk index*

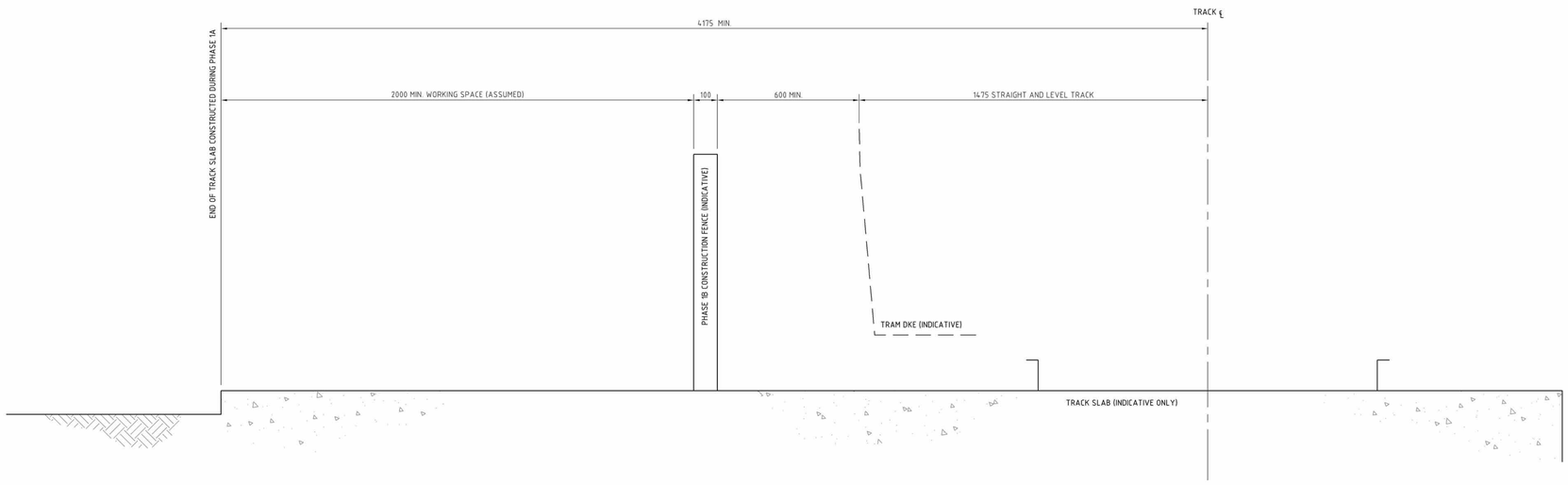
| Description of Risk | Ref. No. |
|---|---|
| Refer to Designer's Hazard Risk Assessment Ref. | |

PB INTERNAL VERSION NUMBER : -

CEC00309294_0075




PLAN
SCALE 1 : 200

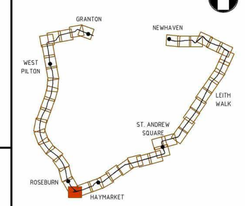



SECTION A-A (B-B SIMILAR)
SCALE 1 : 10

NOTES

1. NORTH POINT IS TO LOCAL GRID.
2. ALL DIMENSIONS IN METRES UNLESS OTHERWISE STATED.
2. THIS DRAWING IS NOT FOR CONSTRUCTION.
3. DWG HUMMINGBIRD REF: #77322
   PDF HUMMINGBIRD REF: #77323

LOCATION DIAGRAM




| REV. | DESCRIPTION OF REVISION | DRN. | CHKD. | APP. | DATE |
|---|---|---|---|---|---|
| 1 | FOR INFORMATION ONLY | NV | AJ | AJ | 19/11/07 |

DRAWING STATUS
**For Information Only**

**EDINBURGH TRAM NETWORK**

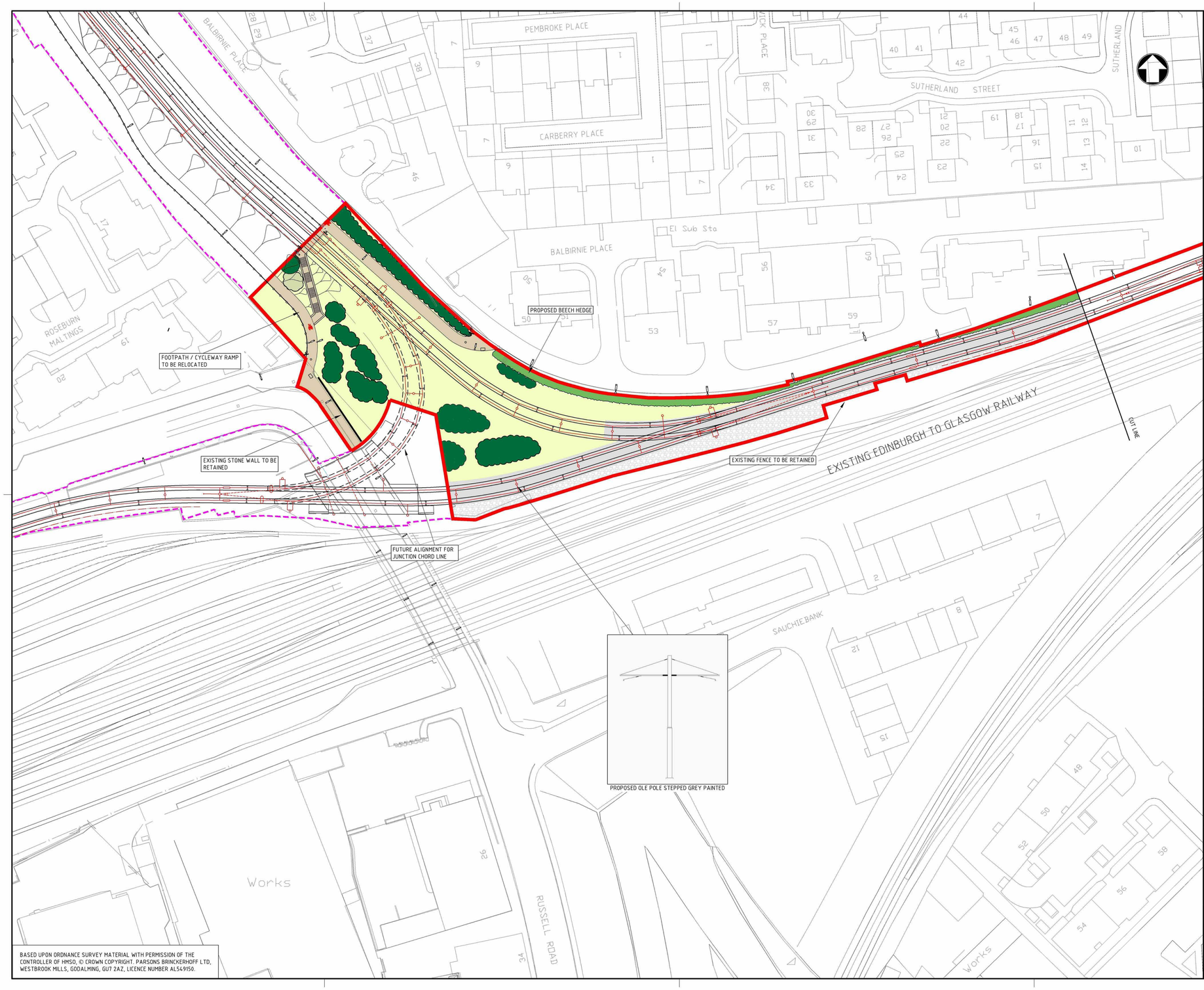
PARSONS BRINCKERHOFF
MANCHESTER TECHNOLOGY CENTRE
OXFORD ROAD
MANCHESTER M1 7ED

HAYMARKET TO ROSEBURN JUNCTION
PHASE 1A/1B SEGREGATION - MINIMUM EXTENT OF TRACK SLAB CONSTRUCTED DURING PAHSE 1A AT ROSEBURN JUNCTION EAST

| | |
|---|---|
| DRAWN BY: VarleyN | CHECKED BY: JORYA |
| APPROVED BY: JORYA | ORIGINAL DRAWING SIZE: A1 |
| DATE: 19/11/2007 | SCALE(S): AS SHOWN |
| DRAWING NUMBER: ULE90130-02-DRG-00007 | REV.: 1 |

PB INTERNAL VERSION NUMBER : 1

CEC00309294_0076

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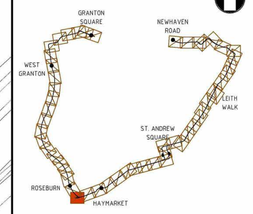
NOTES

1. LIMITS OF DEVIATION AND PRIOR APPROVAL SITE BOUNDARY OVERLAP IN VARIOUS AREAS. IN THESE CASES, ONLY THE PRIOR APPROVAL SITE BOUNDARY WILL APPEAR ON THESE DRAWINGS.
2. COLOURS USED ON THIS DRAWING HAVE BEEN CHOSEN FOR CLARITY OF PRESENTATION AND ARE NOT NECESSARILY REPRESENTATIVE OF ACTUAL MATERIALS OR FINISHES.
3. THE FOLLOWING ELEMENTS SHOWN ON THIS DRAWING REQUIRE PRIOR APPROVAL: POLES, OVERHEAD LINE EQUIPMENT BUILDING FIXINGS, TRAM STOP SHELTERS AND RELOCATED BUS SHELTERS. OTHER ELEMENTS ARE SHOWN TO PROVIDE CONTEXT FOR THIS APPLICATION BUT DO NOT REQUIRE PRIOR APPROVAL.
4. THIS DRAWING HAS BEEN PRODUCED FOR THE PRIOR APPROVAL APPLICATION AND IS NOT TO BE USED FOR CONSTRUCTION.

KEY

- LIMIT OF DEVIATION
- LIMIT OF LAND TO BE ACQUIRED OR USED (LLAU)
- PRIOR APPROVAL SUBMISSION SITE BOUNDARY
- HEDGEROW
- CONCRETE
- GRAVEL FINISH
- TARMAC FOOTWAYS
- GRASS
- OLE POLE AND WIRE RUN
- TRAM TRACK
- STREET LIGHTING COLUMN
- STEPPED ACCESS

LOCATION DIAGRAM




| REV. | DESCRIPTION OF REVISION | DRN. | CHKD. | APP. | DATE |
|---|---|---|---|---|---|
| 1 | FIRST ISSUE | CC | MS | KS | 09/09/07 |
| 2 | ISSUED FOR PRIOR APPROVAL | MOH | MS | KS | 01/11/07 |

DRAWING STATUS

**Issued for External Approval**

**EDINBURGH TRAM NETWORK**

PARSONS BRINCKERHOFF
SDS
CITY POINT
65 HAYMARKET TERRACE
EDINBURGH EH12 5HD

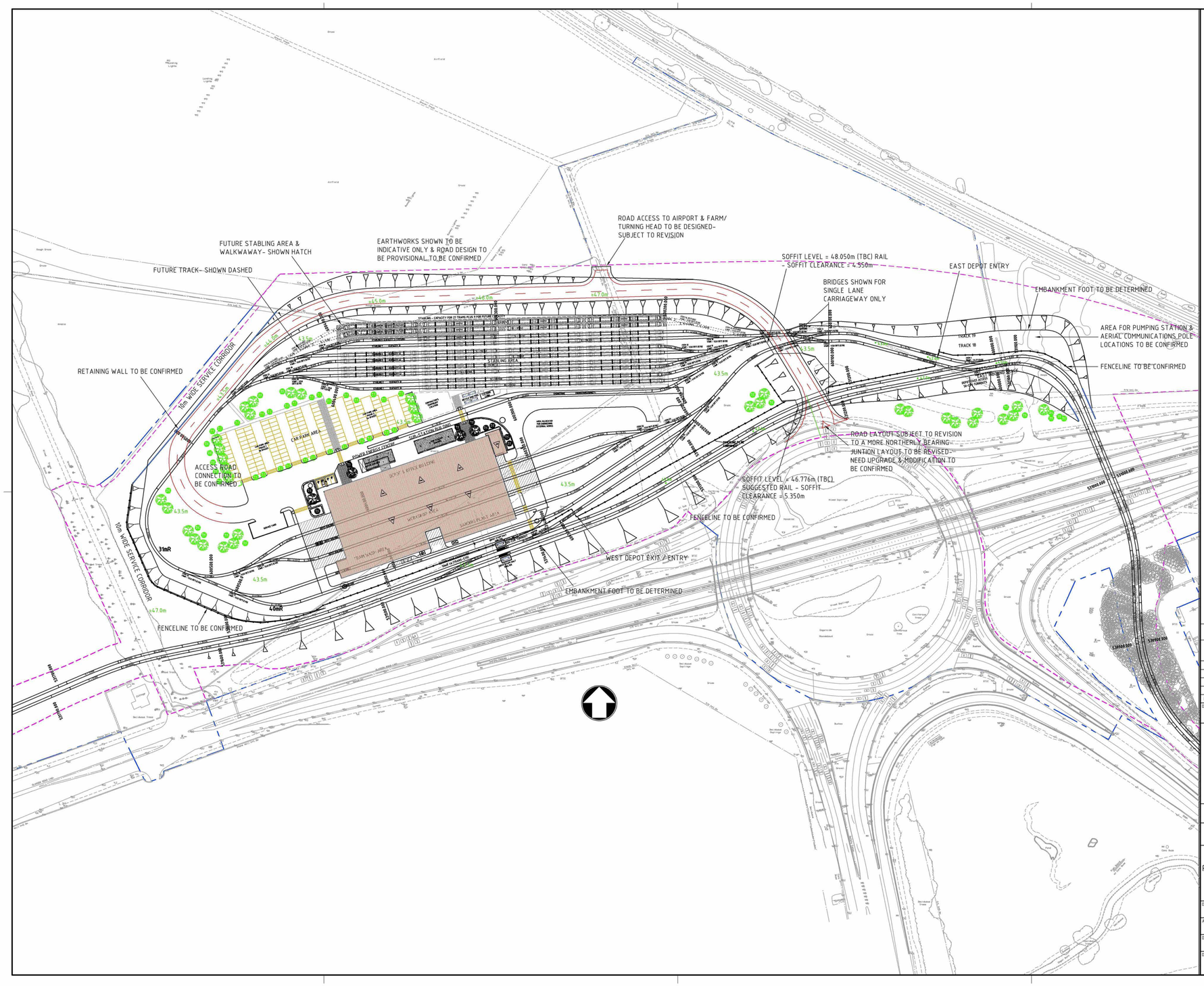
HAYMARKET TO ROSEBURN JUNCTION
HAYMARKET YARDS TO RUSSELL ROAD
PLANNING DRAWINGS BATCH 2/02
GENERAL ARRANGEMENT SHEET 2 OF 2

| DRAWN BY | CHECKED BY |
|---|---|
| CROMARC | STACYM |
| APPROVED BY | ORIGINAL DRAWING SIZE |
| SHUDALLK | A1 |
| DATE | SCALE(S) |
| 16/11/2006 | 1:500 |

| DRAWING NUMBER | REV. |
|---|---|
| ULE90130-02-PLG-00023 | 2 |

PB INTERNAL VERSION NUMBER : 2

CEC00309294_0077




NOTES

1. NORTH POINT IS TO OS GRID.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT PARSONS BRINCKERHOFF DRAWINGS AND SPECIFICATIONS.
3. DO NOT SCALE OFF THIS DRAWING, WORK ONLY TO DIMENSIONS SHOWN. ALL DIMENSIONS IN METRES UNLESS OTHERWISE STATED.
4. ALL LEVELS SHOWN TO BE INDICATIVE.
5. 43.6m LONG TRAM DESIGN OPTION.

HB REF: #25506
PDF HB REF: #

| REV | DESCRIPTION OF REVISION | DRN | CHKD | APP | DATE |
|---|---|---|---|---|---|
| 7 | DETAILED DESIGN | SS | ISB | | 10.09.07 |
| 6 | ISSUED FOR TENDER PURPOSES ONLY | SS | ISB | | 28.09.06 |
| 5 | PRELIMINARY DESIGN ISSUED FOR EXTERNAL APPROVAL | SS | ISB | | 27.06.06 |
| 4 | ISSUED FOR IDC | MAP | SS | | 09.06.06 |
| 3 | PRELIMINARY DESIGN | MAP | SS | | 26.05.06 |
| 2 | ISSUED FOR COMMENT | MAP | SS | | 05.05.06 |
| 1 | ISSUED FOR COMMMENT | NV | DJT | NR | 09.03.06 |

DRAWING STATUS

**For External Approval**

**EDINBURGH TRAM NETWORK**

PARSONS BRINCKERHOFF

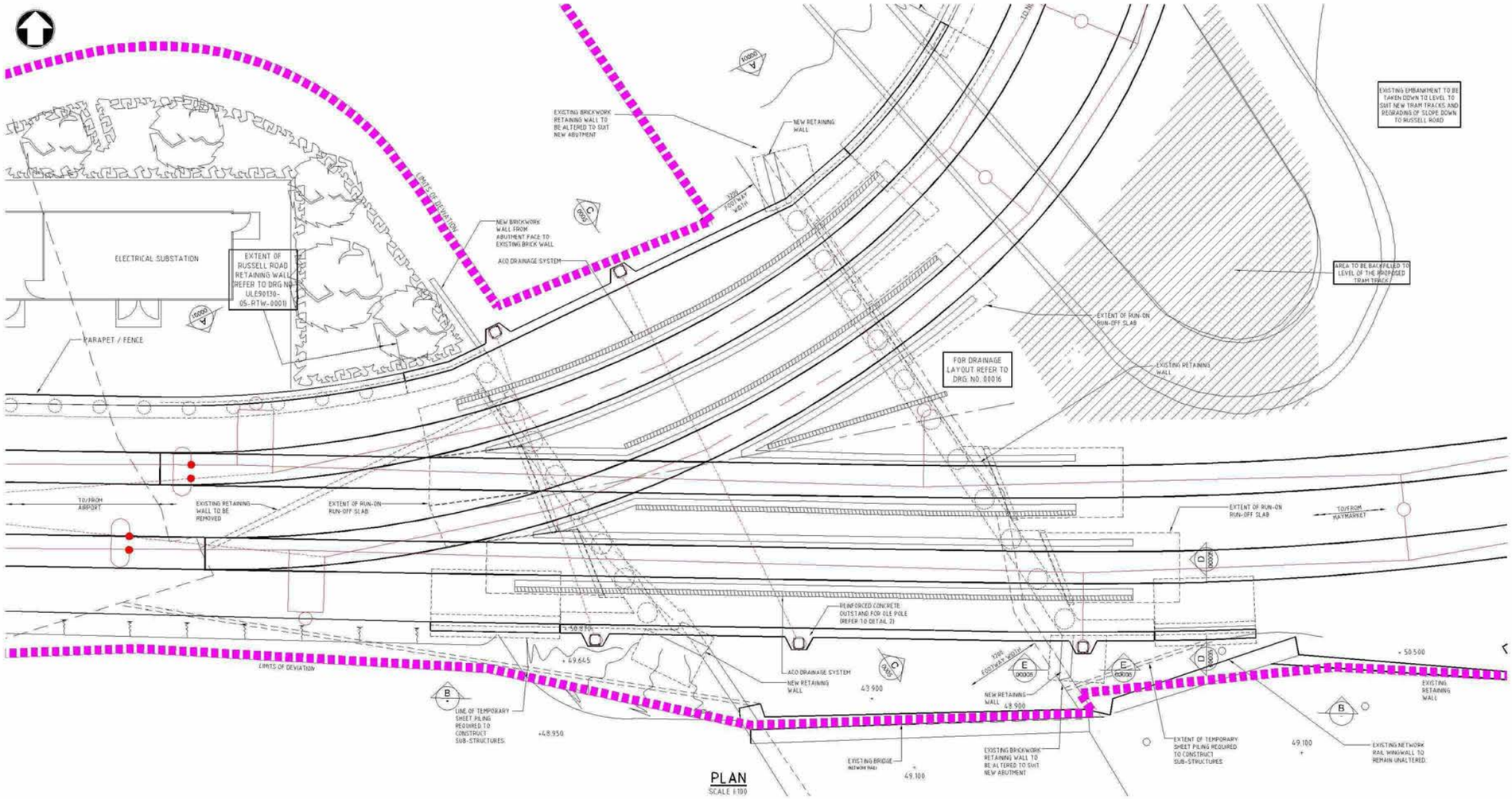
PARSONS BRINCKERHOFF MANCHESTER TECHNOLOGY CENTRE OXFORD ROAD MANCHESTER M1 7ED

GOGAR DEPOT
PROPOSED MAINTENANCE & STABLING LAYOUT
SITE PLAN GENERAL ARRANGEMENT
DEPOT & OFFICE BUILDING LOCATION

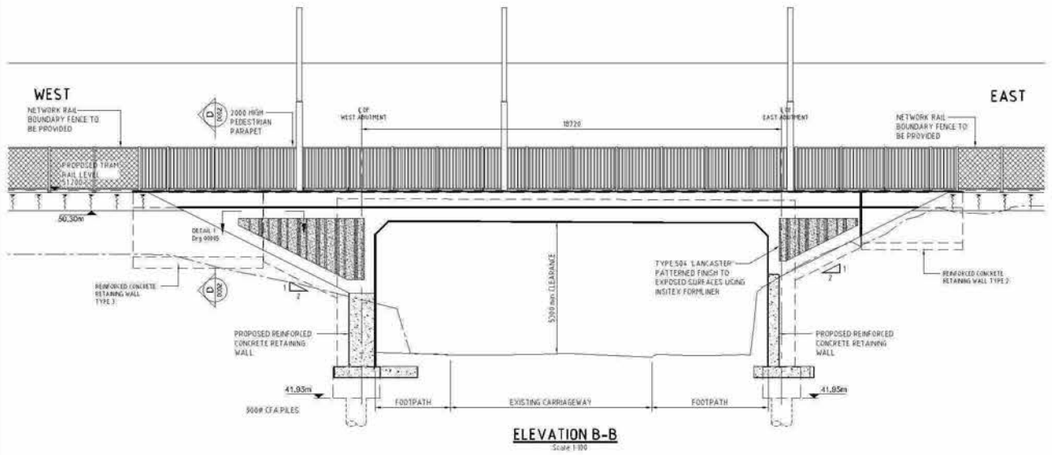
| | |
|---|---|
| DRAWN BY: PRO/OKM | CHECKED BY: SchattenS |
| APPROVED BY: | ORIGINAL DRAWING SIZE: A1 |
| DATE: 02/05/2006 | SCALE(S): 1:1000 |
| DRAWING NUMBER: ULE90130-06-DEP-00001 | REV.: 7 |

PB INTERNAL VERSION NUMBER - 7

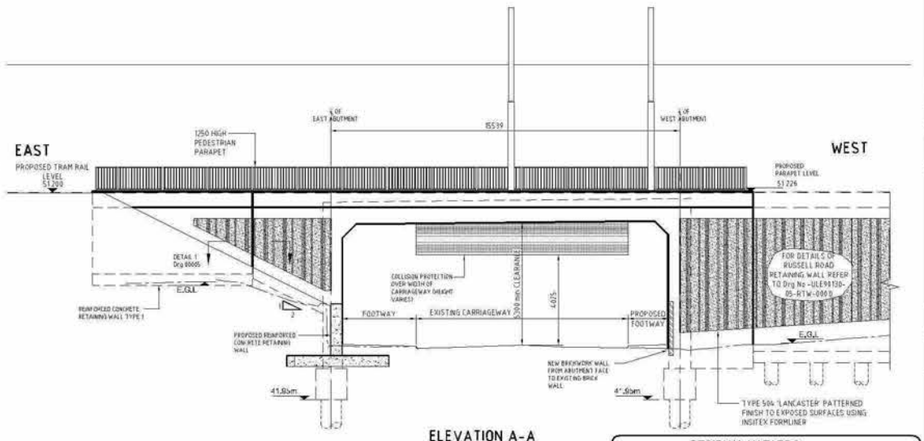
CEC00309294_0078




PLAN
SCALE 1:100




ELEVATION B-B
Scale 1:100




ELEVATION A-A
Scale 1:100

## RESIDUAL HAZARDS

The following list provides reference to the Designer's Hazard Risk Assessment and indicates those hazards with a high mitigated residual risk index

| Description of Risk | Ref. No. |
|---|---|
| Services, underground, overhead, within structure | 8 |
| Construction adjacent to live railway/ depot | 7 |

## NOTES

1) This drawing to be read in conjunction with the relevant Specification and all other relevant drawings.
2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.
3) All dimensions in millimetres unless otherwise noted.
4) All levels in metres unless otherwise noted.
5) All structural concrete to be Grade C40/50. Parapet plinth concrete to be Grade C32/40 air entrained in accordance with BS8500 U.N.O.
6) All cover to reinforcement to be in accordance with BS8500.
7) All reinforcement to be Grade 500B in accordance with BS4449:2005.
8) All exposed concrete surfaces shall be impregnated with silane.
9) Max. water cement ratio shall be 0.4
10) All parapet anchorages to be hot dipped galvanized or stainless steel.
11) All buried surfaces shall be treated with two coats of Bitumen paint in accordance with the Specification for Highways Works.
12) Further details of the all identified risks associated with this designer can be found in the relevant Designers Risk Assessment (Ref ULE90130-05-DRA-00001). Those risks identified as having a high residual risk are detailed in the Residual Hazards Box below and are captured within the Structures section of the Project Residual Risk Register.
13) All finishes to be agreed with City of Edinburgh Planning Department.
14) The Contractors attention is drawn to the fact that in order to construct this Structure a full road closure of Russell Road is required. This closure as been agreed with the City of Edinburgh in principle. However, it is the contractors responsibility to ensure that they liaise with the relevant departments in the Council to obtain full permission for the road closure. Adequate provision for obtaining this closure should be provided in the Contractors programme.
15) Details of driver warning sensors and headroom signage to be agreed with Network Rail

| REV | DESCRIPTION OF REVISION | DRN | CHKD | APP | DATE |
|---|---|---|---|---|---|
| 3 | ISSUED FOR EXTERNAL APPROVAL | JB | ET | CCW | 26/09/07 |
| 2 | WEST ABUT. NO.OF PILES AMENDED | JB | ET | CCW | 21/08/07 |
| 1 | ISSUED FOR INTERNAL REVIEW | JB | ET | CCW | 14/08/07 |

DRAWING STATUS:
**ISSUED FOR EXTERNAL APPROVAL**

tie

**EDINBURGH TRAM NETWORK**

PB PARSONS BRINCKERHOFF
CBS
CITY POINT
65 HAYMARKET TERRACE
EDINBURGH EH12 5HD

RUSSELL ROAD UNDERBRIDGE
STRUCTURE S20

GENERAL ARRANGEMENT - SHEET 1 OF 2

| | |
|---|---|
| DRAWN BY: J BRANNAN | CHECKED BY: E.TOLPENZNIKOVS |
| APPROVED BY: C. WALKER | ORIGINAL DRAWING SIZE: A1 |
| DATE: 06/11/06 | SCALE@: AS SHOWN |
| DRAWING NUMBER: ULE90130-05-BRG-00004 | REV: 3 |

PB INTERNAL VERSION NUMBER :-

CEC00309294_0079